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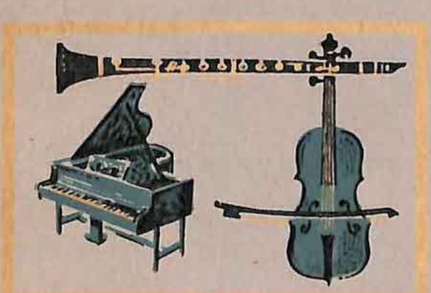
SCIENCE ON THE MARCH

UNIT SEVEN

HEARING AND SEEING



656

SCIENCE ON THE MARCH

UNIT SEVEN

HEARING AND SEEING

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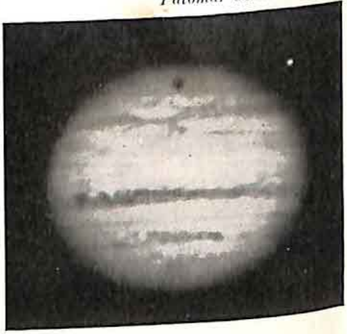
Courtesy, Lick Observatory
The Moon.

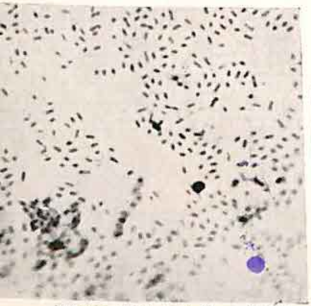
Saturn.
Courtesy, Mount Wilson and Palomar Observatories

New York Times
The biggest telescope using lenses. Yerkes Observatory, U.S.A.

Courtesy, Mount Wilson and Palomar Observatories
Surface of the Moon.

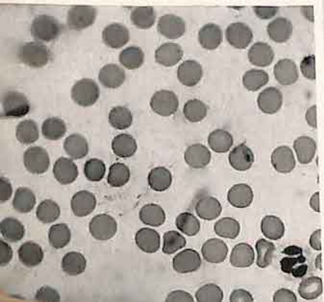
Jupiter.
Courtesy, Mount Wilson and Palomar Observatories



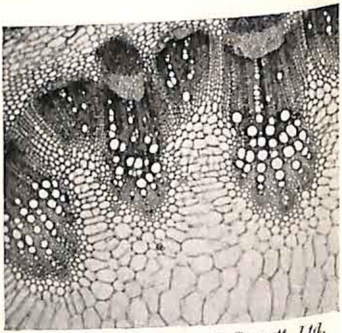


Messrs. Flatters & Garnett Ltd.
Bacteria.

Blood corpuscles.
Messrs. Flatters & Garnett Ltd.



Triple nose microscope
Messrs. W. Watson & Sons Ltd.



Messrs. Flatters & Garnett. Ltd.
Transverse section of a sunflower stem.

Spirogyra.
A. Harold Bastin

SCIENCE ON THE MARCH

UNIT SEVEN

HEARING AND SEEING

John A. Clark
Edith Lillian Smith
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The first nine units of SCIENCE ON THE MARCH are:

1. Air and You.
2. Water and Life.
3. The Weather and the Earth.
4. Life and Food.
5. Health.
6. Energy and Engines.
7. Hearing and Seeing.
8. Electric Currents.
9. Electric Motors and Power.

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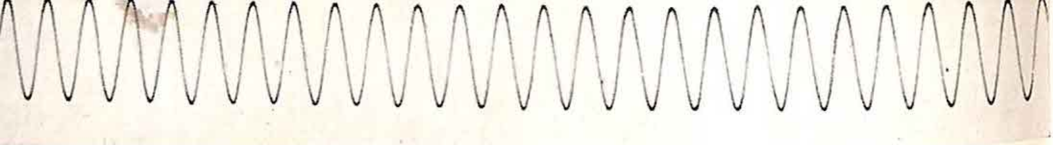
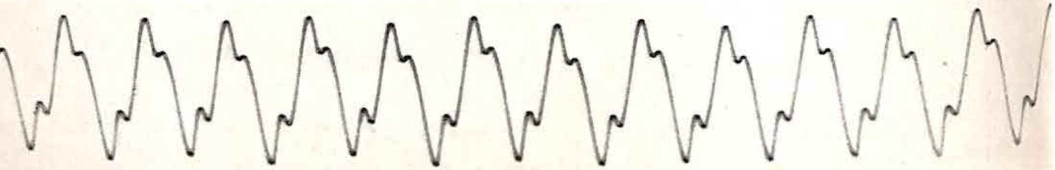


Tuning Fork.



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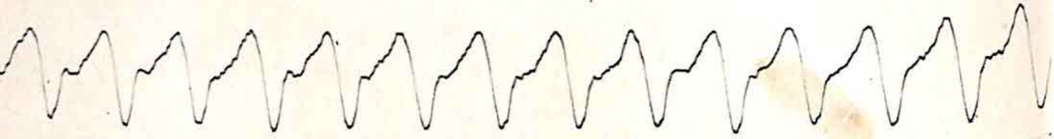
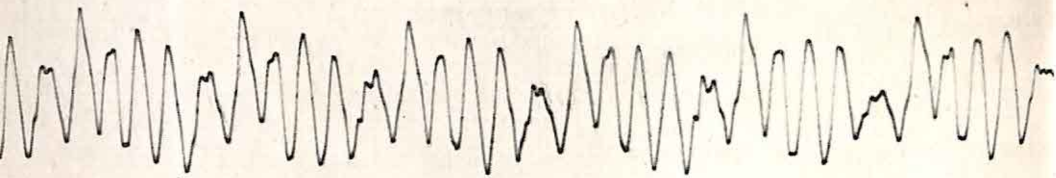
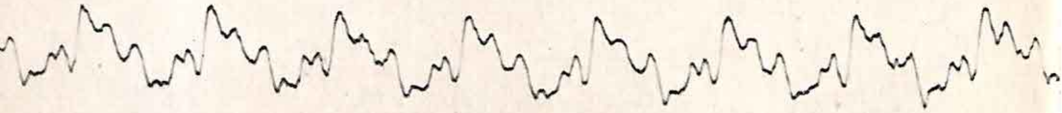


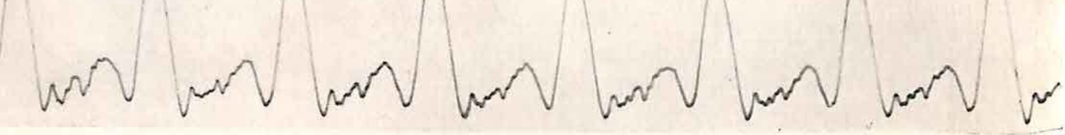
Flute.



Oboe.



Clarinet.



Saxophone.

G. B. Daish & D. H. Fender

Sounds can be represented by wave forms. Musical notes produce regular wave patterns. These photographs show the wave forms of some musical notes produced by different instruments.

Hearing and Seeing

Problem A: WHAT PART DOES SOUND PLAY IN COMMUNICATION?

A PICTURE may remain on the walls of a room for years without giving off sound, but if it falls to the floor while you are in the room, you will hear a crash. A sound has been produced. Likewise a whistle in your pocket is silent. It will remain silent until it is blown. When it is blown, its shrill sound can be heard for some distance in all directions. How does the sounding whistle differ from the silent one? To help us answer this question let us study two simple experiments.

Problem A: What part does Sound play in Communication?

Question 1. **What is Sound?**

Hold one end of a rubber band in the teeth, and stretch it by pulling upon the other end with your hand. While the band is tightly stretched, pull it to one side about an inch and then let it go. If you do this, you will probably hear it give off a musical sound and see it moving backwards and forwards (vibrating). When the band ceases to vibrate, does it still give off sound?

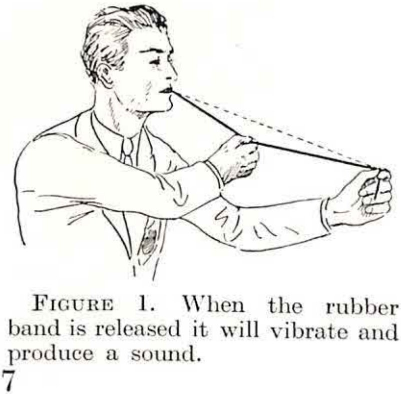


FIGURE 1. When the rubber band is released it will vibrate and produce a sound.

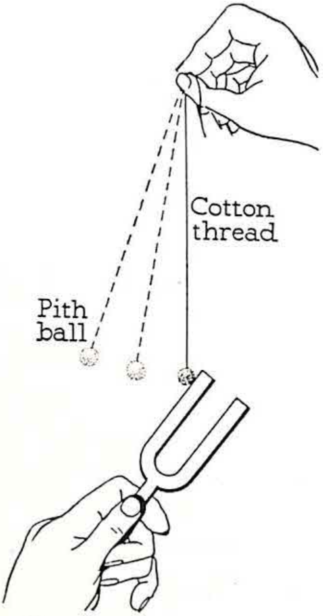


Figure 2. The ball moves when the tuning-fork makes a sound.

Strike a tuning-fork on a piece of wood. The fork will make a sound. But you may not be able to see that the fork is vibrating, especially if the sound is feeble. Now place one of the prongs of the fork close to a suspended pith ball. Why does the ball move ?

What do these two experiments seem to show about bodies that make sounds ?

VIBRATIONS

Is all sound produced by vibrations ? The vibrations of the strings of a violin cause the musical notes. The buzz of the mosquito is due to the vibrations of its wings. The metal diaphragm of a telephone receiver vibrates when in use. You cannot see the vibration but you can often feel it if the person telephoning to you speaks very loudly. Whenever you hear a sound you can be sure that something is vibrating.

Do all vibrating objects produce sound ? If you wave your hand and vibrate it backwards and forwards you do not seem to be able to produce a sound. However fast you do this you cannot hear the vibrations you set up in the air. Why ?

You can buy a special whistle which dogs can hear but you can't. The police sometimes use such whistles with their dogs. Some people can hear the shrill note of a bat, but not everyone. The fact is that when vibrations are too slow or too fast, they do not produce sounds audible to the ear.

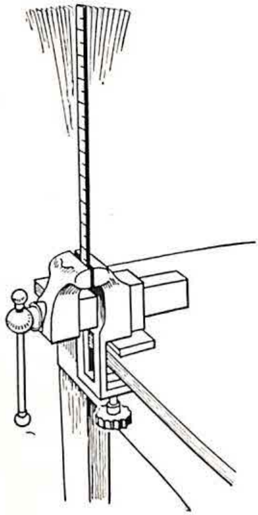


FIGURE 3. A simple experiment to show that a rapidly vibrating rod gives off a sound.

What is the difference between noise and music? Shake a tin with a few nails inside. The movements of the tin set up by the shaking of the nails are irregular and give rise to a mixture of sounds that you call a noise. The violin string vibrates at a regular rate and gives out a beautiful musical note. Only regular vibrations produce sounds that you call music.

SOME THINGS TO THINK ABOUT

1. What vibrating body (or bodies) cause the sound in each of the following: piano, bell, mouth organ, loud-speaker?

2. Why is it necessary to breathe in order to cause the vocal cords to produce sound?

3. " Energy is needed to produce sound." Give one reason to support the above statement.

4. Give one example of a sound produced by the use of each of the following: (*a*) Muscular energy, (*b*) energy from an electric current, (*c*) energy from the wind, (*d*) heat energy.

Question 2. **How does Sound Travel ?**

You have learned that sound is caused by the vibrations of a body and know that it can be heard even when the ear is far from the vibrating body. You have probably seen steam coming from the whistle of a locomotive or a boat before you heard the sound it produced. It takes some time for the sound to travel from one place to another.

You ordinarily move from place to place by walking ; birds usually fly ; wheels roll over a surface ; and a bullet moves bodily through the air. In each of these cases the moving body follows a single path. But when a whistle is blown, its sound can be heard everywhere near it. Thus sound seems to travel in all directions at once. How is this possible ? Before studying the behaviour of air about a body making a sound, let us see if a solid, such as a piece of wood, can be used to carry sound to the ear.

SOMETHING TO FIND OUT : *Does Sound travel easily through solid bodies ?*

If you hold one end of a long rule firmly against the lobe of your ear, you can determine whether a sound produced at the other end will travel through the rule. If the remote end of the rule is scratched ever so lightly with the fingernail, or gently stroked with the finger, or very gently tapped, you will be able not only to hear the sounds produced, but also to tell with your eyes closed which method is being used to produce them. Although nobody else will be able to hear the sounds, they will be wonderfully clear to you. In this case the sound travelled through the rule rather than through the air.

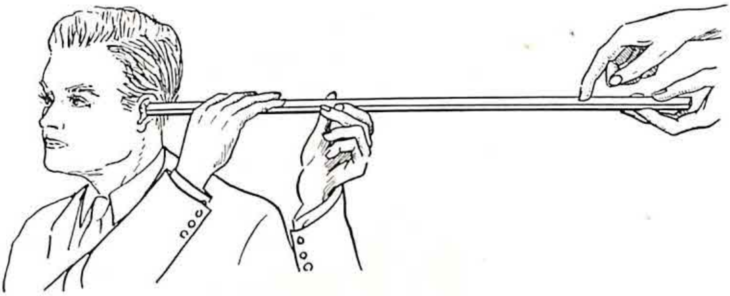


FIGURE 4. Wood carries sound better than air does.

If you now place the palm of your hand over the ear and then gently scratch, first the back of your hand, then your wrist, and finally your elbow, you can find out how well or how poorly your body carries sound.

Does sound travel as well through the human body as through wood?

Can you give an example from your experience of sound travelling through a solid?

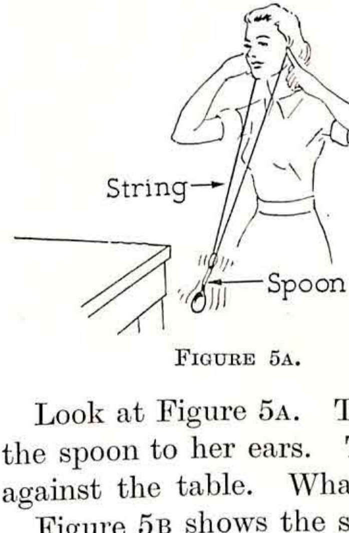


FIGURE 5A.

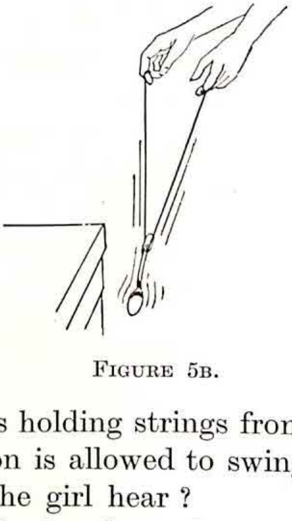


FIGURE 5B.

Look at Figure 5A. The girl is holding strings from the spoon to her ears. The spoon is allowed to swing against the table. What does the girl hear?

Figure 5B shows the spoon swinging from the girl's fingers. What does she now hear when the spoon hits the table?

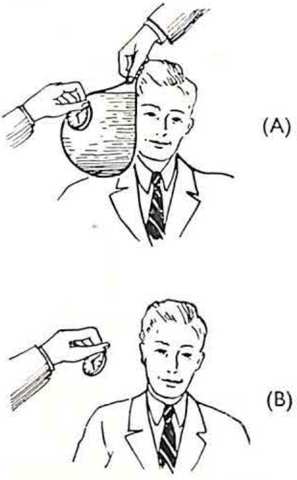


FIGURE 6.

In this figure the boy has his ear against a balloon filled with water. Can he hear the ticking of the watch on the other side of the balloon ?

In this Figure the balloon has been removed. How does the sound of the watch compare with its sound through the balloon ?

SOMETHING YOU MAY CARE TO DO

Make a telephone that will work over a considerable distance. Get two large tins and pierce a hole in the centre of the base of each. Through the holes pass 50 or 100 yards of thin wire or thick thread and fasten to each end a small nail. Draw the tins apart until the thread is taut. If one of you speaks into a tin while another holds the second tin to his ear the speech will be heard quite plainly.

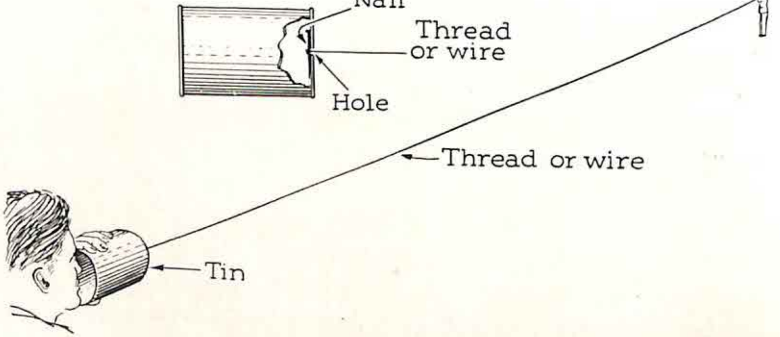


FIGURE 7. Wire telephone.

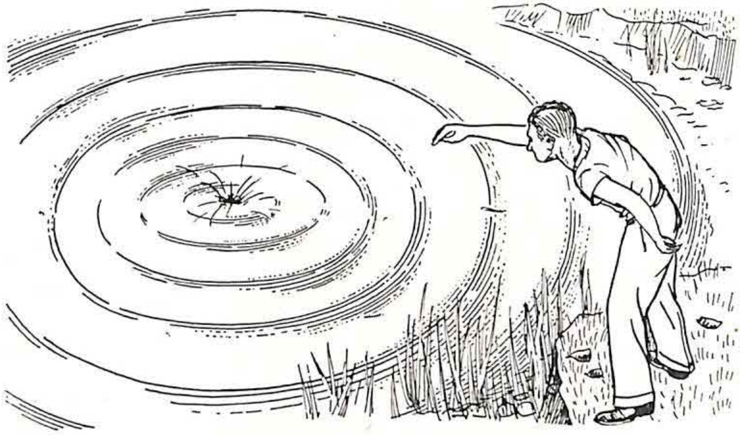


FIGURE 8. The waves spread out in all directions.

SOUND WAVES

Do some disturbances travel in all directions? When you throw a stone into a pool of still water, it disturbs the water. Probably you have seen water waves travel in all directions from the spot where the stone falls. In this case the succession of waves moves along the surface of the water, and there is no disturbance of the water at the bottom of the pool. But swimmers and fishermen have learned that when a sound is made

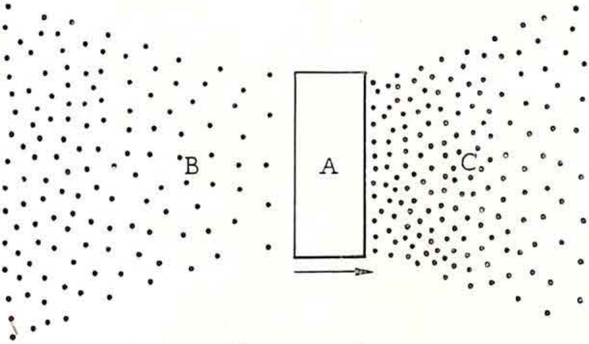
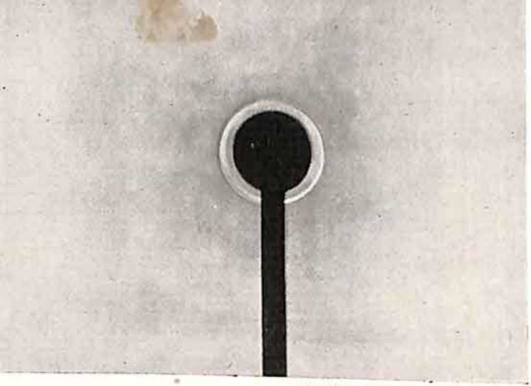
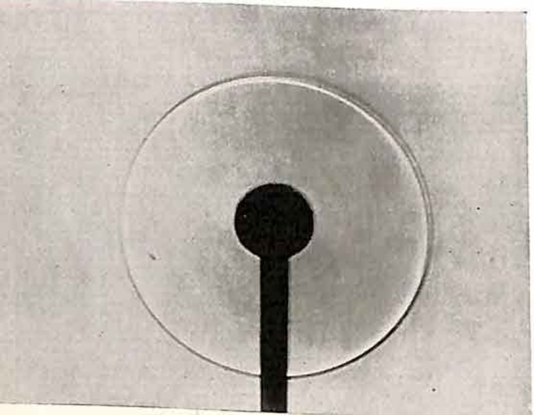


FIGURE 9. When a body making a sound moves, the air is compressed in front of it. What occurs behind it?



Courtesy, Prof. A. L. Foley

FIGURE 10. Photograph of a sound wave shortly after it left the body in the centre which makes the sound.

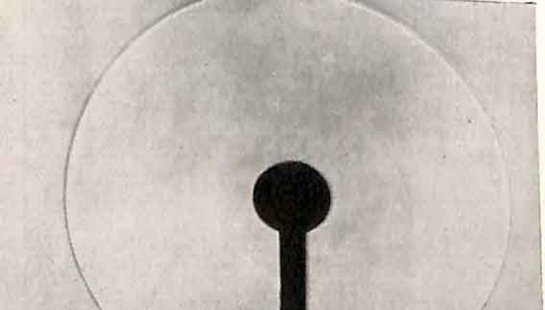


Courtesy, Prof. A. L. Foley

FIGURE 11. The sound wave is shown a few thousandths of a second later.

FIGURE 12. The sound wave still later.

Courtesy, Prof. A. L. Foley



under water, it is carried to all parts of the water. If you should strike two stones together vigorously under water when a swimmer is under water near-by, his eardrums might be injured by the vibrations.

A body making a sound disturbs the air. Such vibrating bodies are usually surrounded by air instead of water. In Figure 9 A represents the end of a tuning-fork which is moving to the right. Notice how the particles of air are crowded together at C, and how they are spread apart at B. The moving fork has thus compressed the air on one side and rarefied it on the other. This compressed condition of the air will not remain at C, but will move forward through the air. Although we cannot see these compressed regions with the eye, it is possible to get photographs of them soon after they start forth from the vibrating body.

As the fork moves backwards and forwards, the air about it becomes filled with compressed and rarefied layers which move out in all directions in all three dimensions. This condition is shown in Figure 13. Since the compressed and rarefied layers follow each other, just as do the crests and troughs of water waves, we speak of them as forming a sound wave. In the case of water waves the water moves *up* and *down* as the wave moves *forward*, but in the case of sound waves the air particles move *backwards* and *forwards* in time with the vibrating body as the compressed and rarefied layers move out through the air.

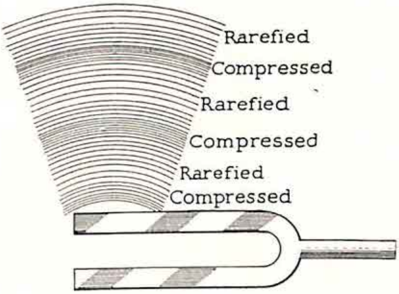


FIGURE 13. How sound travels.

Sound waves travel very fast. A car travelling at fifty miles an hour goes only about seventy-five feet a second, but sound waves travel just a little more than one thousand feet per second. Because of this high speed we seem to hear sounds about us at the instant that they are made. But if a sounding body is one thousand feet away, it will be about a second before we hear the sound it produces. Since sound travels about one-fifth of a mile a second on a summer day, people can judge how far they are from a flash of lightning. They need only count seconds, until they hear the thunder. After dividing the number of seconds by five, they have a rough idea of the distance in miles.

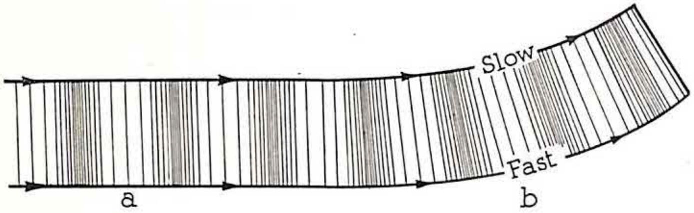


FIGURE 14. Passage of a sound wave through air. (*a*) All the air here is at the same temperature. (*b*) Here there is cold air above and warm air below.

Sound Waves Can be Bent

Sound travels faster in warm air than it does in cool air. We know that the heat from the sun warms the earth quickly during the day. This warm earth makes the air near to it warmer than the air which is further away. Waves of sound thus bend as in Figure 14. *Does a bimetal strip bend like this when it is heated? How would a row of soldiers turn if the tall ones were on one side and the short-legged ones on the other side?*

Figure 15 shows how waves of sound bend on a hot sunny day. So sound starting from a source at S is bent away from a man trying to listen to it at M. When the sun sets the opposite is true, the earth cools quickly, and on a still evening so does the air close to its surface. Figure 16 shows how the sound now bends downwards, so that the observer hears distinctly sounds

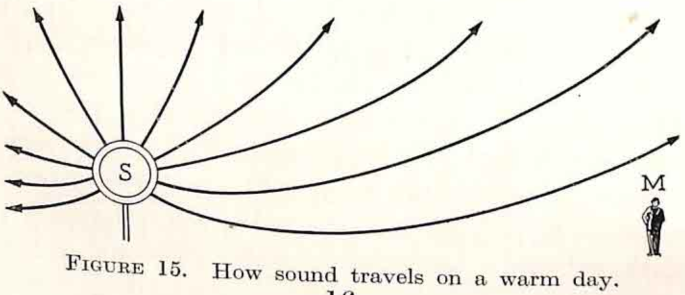


FIGURE 15. How sound travels on a warm day.

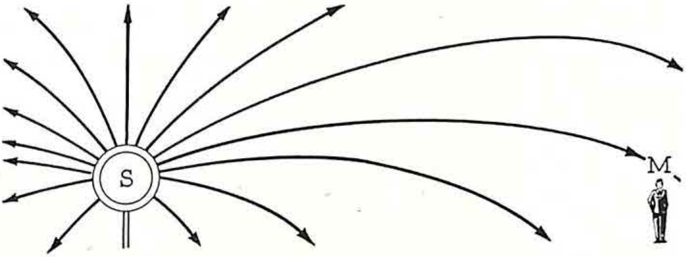


FIGURE 16. How sound travels in the night.

from a great distance away. Try this for yourself: take a portable gramophone to a large field and play it on a still hot day and again on a still clear evening. Is there a great difference?

Sound waves carry energy. Work must be done by a sounding body to set the air in motion and the body loses energy when it vibrates. The air, of course, receives this energy. As the energy of the sounding body becomes less and less, the sound dies down and fades away. For example, a drum ceases to give off sound soon after it has been struck by the drum stick. In another question you will see how men use the energy of sound waves to send and receive messages.

SOME THINGS TO THINK ABOUT

1. Why will sound not be produced in a vacuum?
2. Give a reason why shoes sometimes squeak.
3. Why does a carpet placed on the stairs help to keep a house quiet?

Problem A: What part does Sound play in Communication?

Question 3. **How do we Hear?**

You have probably seen bits of floating wood or leaves or toy boats lifted by small water waves. You have also seen them sink back into the troughs as the waves pass on. Thus the floating object is given an up-and-down motion. Perhaps you have noted that very loud sounds may even cause windows to rattle. Thunder is sometimes said to "shake the house." Since sound waves have energy, you might reasonably suspect that even ordinary sounds would cause light objects to vibrate.

SOME THINGS YOU MAY CARE TO DO

(1) *Can sound waves set columns of air in vibration?* Lower a waxed cardboard tube into a bucket of water. Blow across the open end of the tube. You will hear a low musical note coming from the tube. If the room is quiet perhaps you can hum the note close to the tube and listen to a much louder note coming from the tube. Take a tuning fork and pass it over the mouth of the tube while you raise and lower the tube in the bucket. You will soon hear the air in the tube vibrating in sympathy with the tuning fork. When this happens there will be a great increase in the loudness of the note. This is known as *resonance.* For any given tuning fork resonance occurs best at one particular length of air column. It occurs when the natural note given out by the air in the tube is the same as the note of the tuning fork. The air at the bottom of the tube is stationary in a position called a *node.* The air at the top has the greatest movement back and forth and is in a position called an *antinode.*

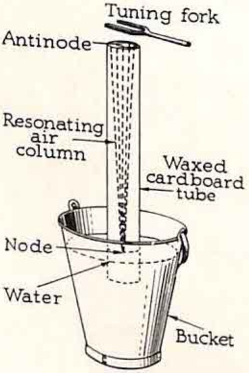
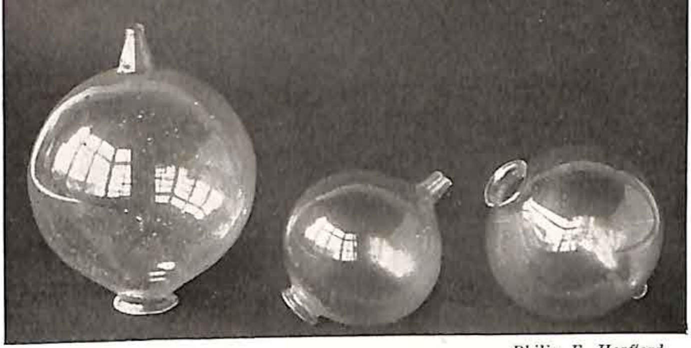


FIGURE 17. Resonance.



Philip E. Heafford

FIGURE 18. Resonators. These glass spheres have an open hole at one side. The air resonates to different notes according to the size of the sphere. The projection at the other side enables you to hear this resonant note.

(2) *Can sound waves set a light membrane in vibration?* A soap film makes a good membrane for studying sound. If the small end of a megaphone is dipped into a soap solution such as is used for blowing bubbles, a membrane will form over the opening when the megaphone is carefully removed from the solution.

If one of you sounds loudly the vowel O-O-Oh across the large opening of the megaphone, others standing close will be able to see the vibrations of the membrane. You will be able to see these vibrations more clearly if you erect on one side of the membrane and about 1 or 2 feet away from it a bright light. Cut a long

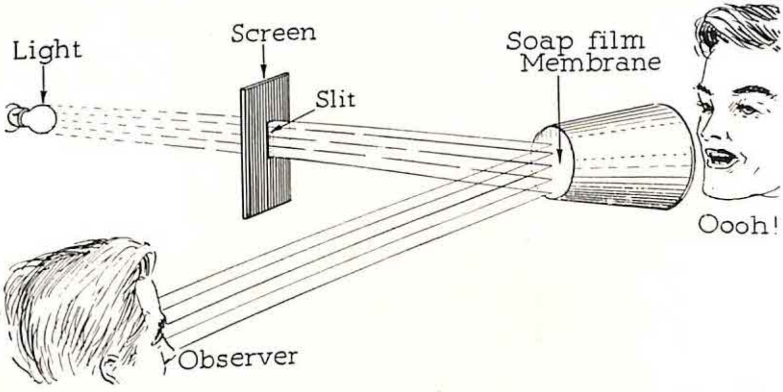


FIGURE 19. How to show that sound waves can cause a soap film membrane to vibrate.

thin vertical slit in a card and put this between the light and the membrane. From the other side look at the reflection of the light in the membrane. Since the membrane or diaphragm is rather large, considerable energy will be required to cause it to move. Thus it may be necessary to make a loud sound to get the best results. Singing produces very interesting and surprising effects.

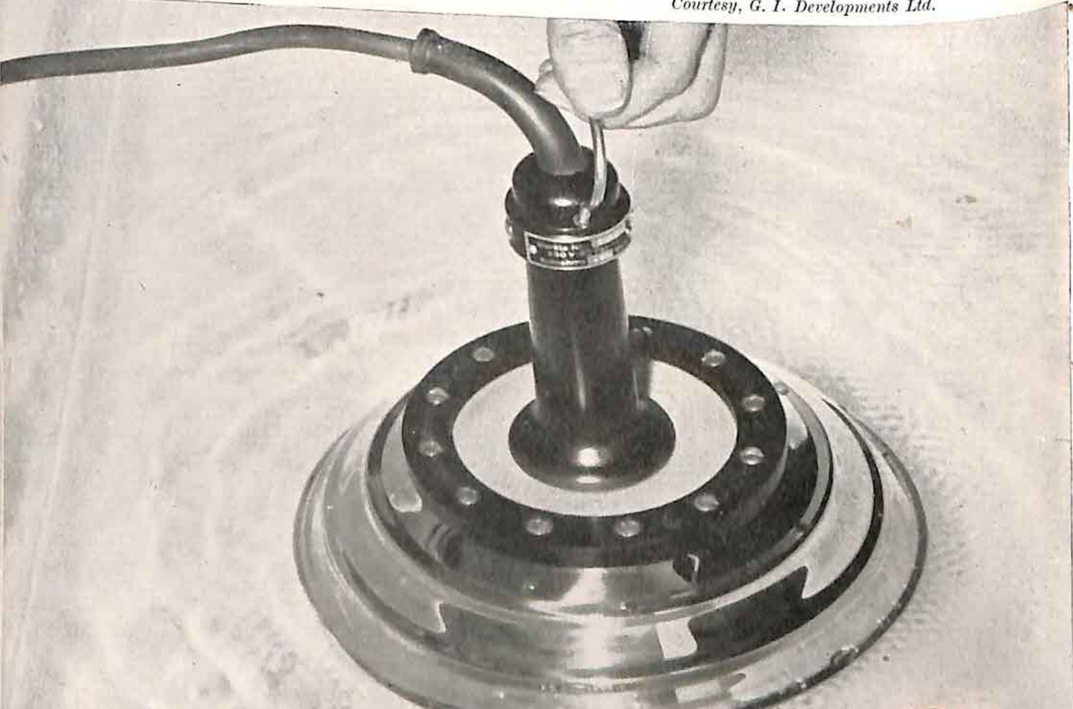
Why is it not desirable to speak directly into the megaphone?

Would more or less energy be required to set a lighter membrane in motion?

What muscles furnish the energy that caused the membrane to vibrate?

FIGURE 20. Vibrations of a frequency of sound are produced by this machine and spread throughout the bath shaking the dirt out of the washing.

Courtesy, G. I. Developments Ltd.



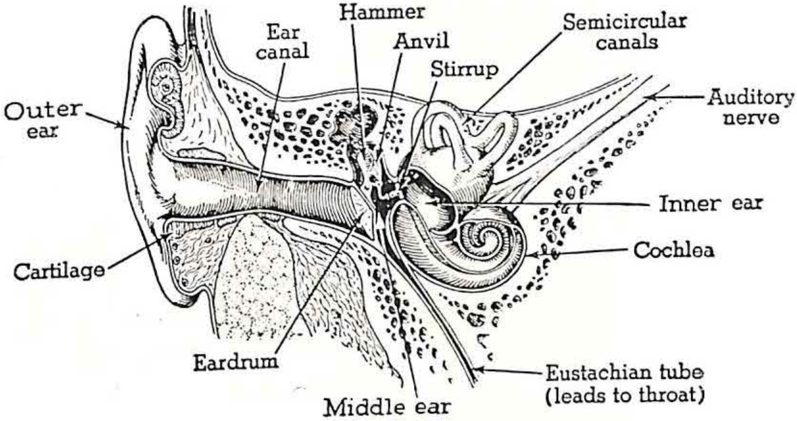


FIGURE 21. The organs of hearing.

THE HUMAN EAR

If you examine the diagram of the human ear, you will note that the outer ear and the ear canal form a sort of megaphone. Across the end of the canal is a small thin membrane called the eardrum. From your experiment it is easy to understand what occurs when sound waves enter the ear. The eardrum membrane is made to vibrate as the soap film membrane did.

A series of bones and canals lie between the eardrum and the nerves that connect with the brain. These parts serve to carry the vibrations set up in the

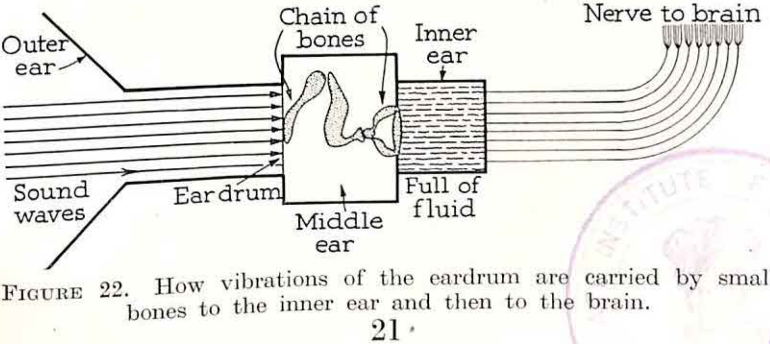


FIGURE 22. How vibrations of the eardrum are carried by small bones to the inner ear and then to the brain.

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drum to the nerve endings. The nerves convey the sound messages to the brain.

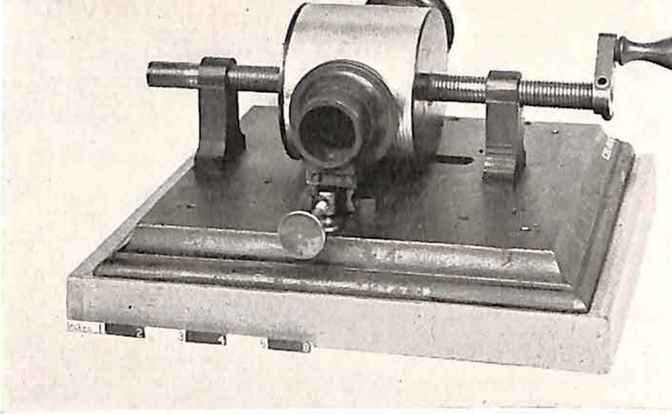
There is also a tube, called the Eustachian tube, running from the cavity within the ear to the throat. This tube is filled with air and serves to keep the air pressure equal on both sides of the eardrum.

When your altitude above sea level alters rapidly either by climbing or descending as, for instance, in a train or an aeroplane, a rapid change occurs in the air pressure on your eardrum. It is then a good idea to open your mouth wide to yawn so that air of the same pressure can easily reach the other side of the eardrum. A very loud sound entering the ear might injure the eardrum. There is less danger of this happening when sound waves can also pass up the tube and strike the back of the eardrum.

The ears are so delicate that they require special care. Although they are well protected by nature, there are some precautions that should be heeded. Don't blow the nose too hard, or squeeze it while blowing, lest germs be forced into the middle ear. Do not try to remove wax by poking about in the ear.

Sound waves may be recorded. Sound waves set the eardrum in vibration. It comes to rest as soon as the waves cease, and is then ready to respond to the next ones that enter the ear. No record of earlier sounds remains.

About sixty years ago Thomas Edison decided to make a membrane or diaphragm delicate enough to vibrate even when faint sounds struck it, and to use it to make records of sounds. At first he used an apparatus similar to the one in your experiment. In place of the soap film he had a thin disc with a short needle fastened to its centre. When the sound waves gathered by the megaphone struck the disc, the disc



Crown Copyright. From an exhibit in the Science Museum, South Kens

FIGURE 23. Edison's phonograph.

and the needle vibrated. The end of the needle was so placed that it would make little dents or impressions in a sheet of tinfoil or wax on a cylinder. Then the cylinder was slowly turned as the sound waves struck the disc so that each vibration could make its own mark. The series of marks produced a line or groove on the surface of the wax. The number and depth of the indentations corresponded, of course, to the vibrations of the disc. After the record was made it could be used to reproduce the sounds that had made the indentations. To do this, the needle was placed at the starting point of the series of dents it made in the wax and the cylinder slowly turned as before.

People spoke of these new and wonderful devices as *talking machines*. You, of course, know them as gramophones. While many improvements have been made, all recording and reproducing instruments still make use of the vibrating disc.

SOME THINGS TO THINK ABOUT

1. Why does a dog prick up its ears ?
2. Of what value is the lobe on the ear ?
3. Why is it dangerous to put small things in the ear ?

Question 4. **Why do sounds Differ ?**

Your ears are almost constantly bombarded by sound waves which produce many different sensations. In *loudness* these sounds vary from the faint buzzing of a mosquito, or the whispering of the wind as it blows through the trees, to the booming of guns and the crashing sounds of thunder. Sounds also differ in highness and lowness (*pitch*). Contrast, for example, the shrill tones of a piccolo and the deep bass voice of the big drum.

On page 7 you found that the sound from the rubber band was not loud until you caused it to vibrate vigorously. When you want to get a loud sound from a drum, you hit it hard. The more vigorously any body vibrates, the greater is the disturbance it produces in the air. Sound waves coming from such vigorously vibrating bodies have enough energy to cause strong reactions in the eardrums. Such sounds are loud. But what causes a difference in pitch ?

SOMETHING TO FIND OUT : *Does Pitch depend upon the number of vibrations of the sounding body ?*

A long rule may be made to vibrate either slowly or rapidly. To secure good results the rule is placed flat on the top of a table or desk and pressed firmly against it about four inches from the edge, as shown in Figure 24. First place the rule so that about two feet of it projects beyond the table. Pull it down and then let it go and observe its motion. To secure a good note, only about one foot should project beyond the table. If you change the rule and repeat the experiment, you will probably notice a decided difference in pitch.

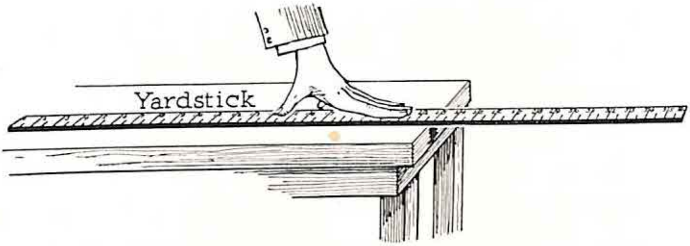


FIGURE 24. The shorter the rule the higher the pitch of the sound produced.

Some pupils can produce all the notes of the scale with this simple device.

How could you tell the rule vibrated more slowly when it was two feet long than when it was one foot long?

Which produced the lower note: the one-foot rule or the six-inch rule?

Which produced the more waves per second?

How does the pitch of a note change as the number of waves per second is increased?

SOMETHING YOU MAY CARE TO DO

Suspend eight medicine bottles from a strong steady support. Pour a different quantity of water in each bottle. Adjust the quantity so that when each bottle is struck with a wooden rod the notes of an octave of a

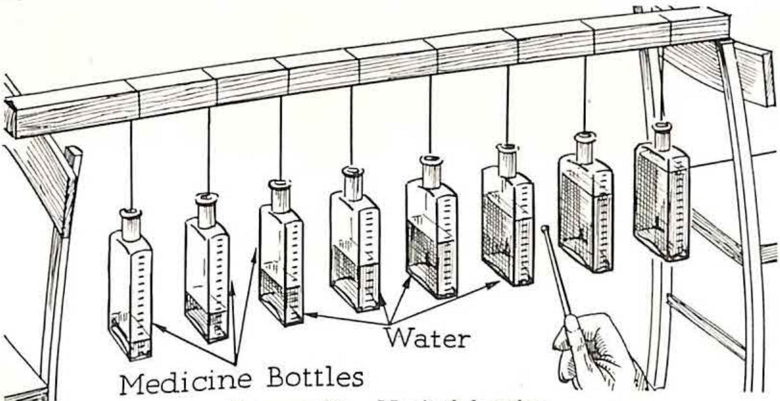


FIGURE 25. Musical bottles.

musical scale are produced. With some practice you will be able to play a number of simple tunes. Instead of using glass bottles you could use metal rods of different lengths, but their lengths are more difficult to adjust.

PITCH, LOUDNESS AND QUALITY

The ear detects differences in pitch. When the number of vibrations coming from a body is doubled, the pitch of the sound produced is raised. The ear easily recognizes a note due to exactly twice as many vibrations as another note. This difference in pitch is called an *octave*. On this page you can see two vibrating strings. One of them gives off twice as many waves as the other. The sounds will thus be an octave apart. For example, if one sound is caused by 200 vibrations per second and another by 400 vibrations per second, the second is an octave higher than the first.

FIGURE 26. This string produces half as many waves as the one below in Figure 27.

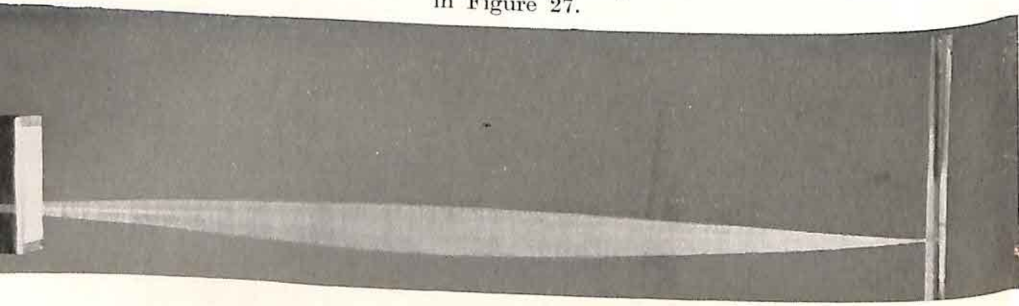
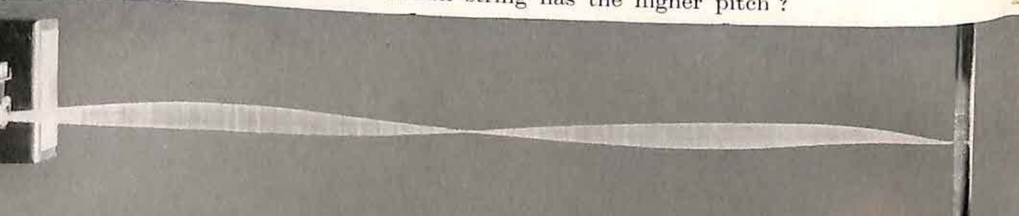


FIGURE 27. Which string has the higher pitch ?



Why sounds differ in quality. There is another difference in sounds even when they have the same pitch and loudness. No one would confuse a note played on a violin with the same one played on a horn. This kind of difference enables a dog to recognize its master's voice and you to identify people when you hear them speak. Differences of this kind are surely not due to loudness. They are also not a matter of pitch, for you can tell a saxophone from a violin even when both produce the same note on the scale. Rather, such variation in sounds is called *quality.*

The photographs on this page show two vibrating strings giving tones of about the same pitch and loudness. You will note that they are not vibrating in exactly the same manner. One may be more pleasing than the other. The sounds produced are said to differ in quality.

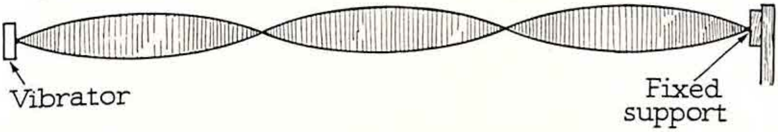


FIGURE 28. Pure tone waves.

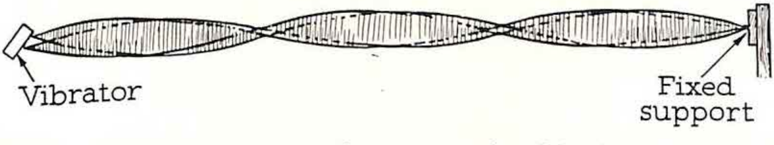


FIGURE 29. Can you see why the waves produced by these two strings are different in quality?

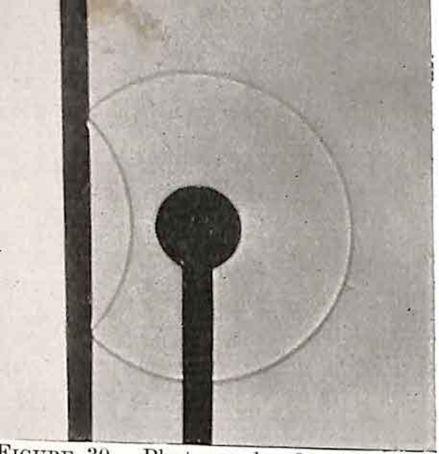


FIGURE 30. Photograph of a sound wave being reflected.

Sound waves may be reflected. You probably have seen water waves turn back when they strike against large objects. Sound waves will also turn back from solid surfaces, such as the walls of a room. Figure 30 shows a sound wave just as it is being reflected from a plane surface. Thus you often hear a speaker by sound waves that come to your ears directly through the air and by those that come to them by reflection. Usually the reflected waves reach the ear at about the same time so that you hear them as a single sound. But if the sound waves are reflected from a distant object, such as a cliff, you may hear both the direct sound and later the reflected one. The second one is called the *echo.*

SOME THINGS TO THINK ABOUT

1. Why are long, heavy strings used to produce the low notes of a piano ?

2. Account for the fact that, although a violin string will give off notes of the same pitch whether it is plucked or bowed, it produces notes of different quality.

3. Why is it difficult to hear well in some rooms ?

Question 5. **What are Hearing Aids and how do they Work ?**

As you have seen, the ear is composed of three sections, the outer ear, the middle ear and the inner ear. The nerve endings in the inner ear are connected to the hearing centres in the brain and are the means by which we hear. Sometimes a person either cannot hear at all, or hears all sounds feebly, or hears to a different extent notes of different pitches throughout the musical scale. Often these people are considered to be less bright or even " backward " when really the only fault is that they do not hear and therefore understand as other people do. Deaf people are not dumb ; their organs of speech are quite normal but, unless trained by special methods, cannot learn to make the sounds of speech.

Deafness can be caused by either a full or a partial failure of the middle ear or inner ear. It is rare for any one of us to have trouble with the outer ear or with the hearing centres in the brain.

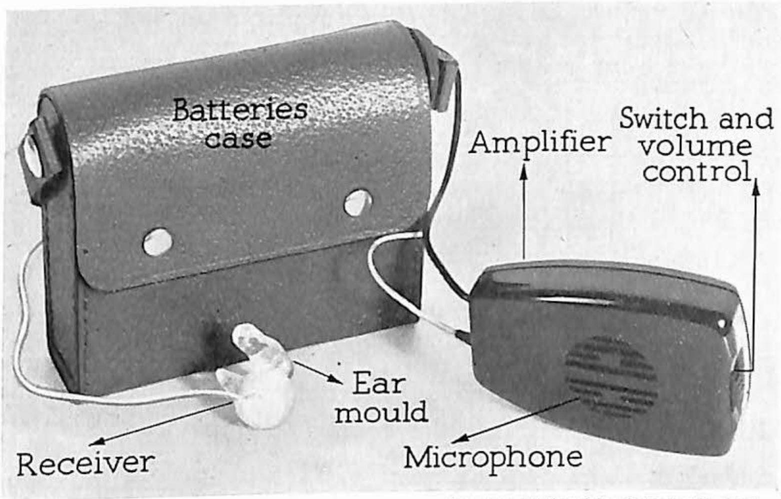
Deafness due to failure in the middle ear affects all pitches but more particularly the low notes. If a suitable strengthening of the patterns of sound received is provided, then a balanced hearing and consequent understanding occurs. The middle ear is sensitive to infections of various kinds like the common ailments, measles, scarlet fever, diphtheria, whooping cough and influenza. Sometimes nasal and throat infections can cause trouble in the middle ear via the Eustachian tube. The use of modern drugs has diminished the number of operations on the middle ear by clearing up some of the worst types of infection. In young children adenoids too can cause the Eustachian tube to become blocked. This is easily seen by a doctor and the deafness quickly cured by treatment of the adenoids.

Failure of the inner ear, or of the nerve endings to be found there, gives a deafness which varies according to the pitch of the note. The loss is greater the higher the pitch of the note and sometimes many of the higher notes are not heard at all. Thus some noises are heard well but not others, so that ordinary speech or music is not clearly heard as it is intended to be. Sometimes, in severe cases, the person only hears a few notes in the whole range of the musical scale. An elderly person frequently cannot hear the high-pitched shrill notes of a bat, which a child hears easily.

School authorities have different ways of testing to what extent a child is deaf or not. Tuning forks, gramophone records and electric audiometers like the one in Unit 1 page 19 are used to help to discover if a child responds to every note equally. Electric audiometers are most useful instruments, having one control for the pitch of the note the instrument emits and another for the strength of the chosen note. The child listens by means of earphones and is able to tell the operator which notes he hears and when he hears them. Often children do not know that they cannot hear certain notes.

What precautions can you take to prevent infection in the ear? If you have a cold or catarrh do not go to swim. Keep your ears clean and if you have a discharging ear see a doctor about it. In fact go early to see a doctor if you suspect any infection in your ear which causes an ache. Treatment in the early stages is relatively easy.

The modern hearing aid is really only an electrical set of apparatus designed to increase the strength of

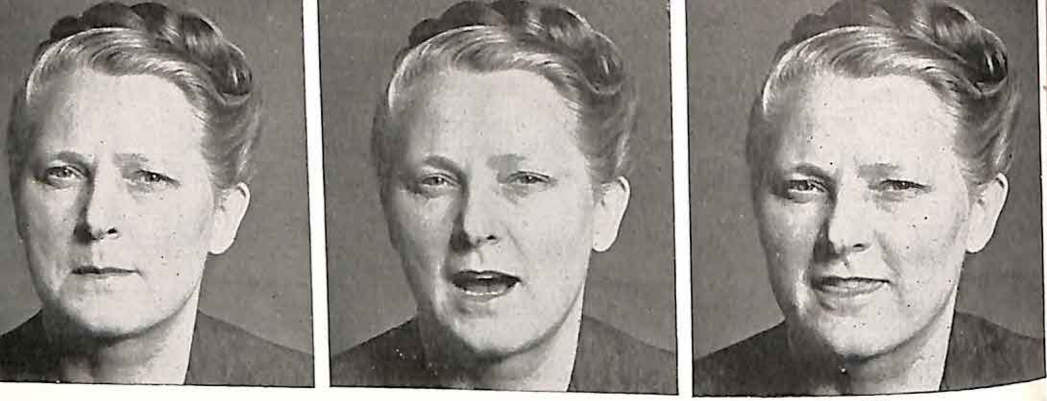


Courtesy, National Institute for the Deaf

FIGURE 31. An early type of hearing aid.

the sound waves which arrive in the ear. A microphone receives the incoming sound waves from the source and turns them into electrical waves. An amplifier strengthens these electrical waves and finally a receiver converts these greatly strengthened electrical waves into sound waves again. The whole aid is so arranged that it is convenient to carry and wear. The microphone and amplifier of the early type of hearing aid as illustrated in Figure 31 were usually built together in a small case. The receiver was very small and mounted in plastic moulded to fit the ear. It is now possible to make hearing aids so small that they can be partly enclosed in the framework of a pair of spectacles and partly hidden in the folds of the hair. A simple volume control is used to regulate the amount of strengthening of the sound.

However, there are a few people who find that the miniature receiver fitted inside the outer ear is not as good as a small vibrator mounted close to the



Photos Vera Elkan

FIGURE 32. Lip reading. Can you "see" her saying the word Bath as "b", "a" and "th"?

bone behind the ear. The vibrations are then conducted through the bones to the nerve centres in the inner ear. These "bone conduction" vibrators unfortunately use much more electrical power and do not give good reproduction of the high-pitched notes.

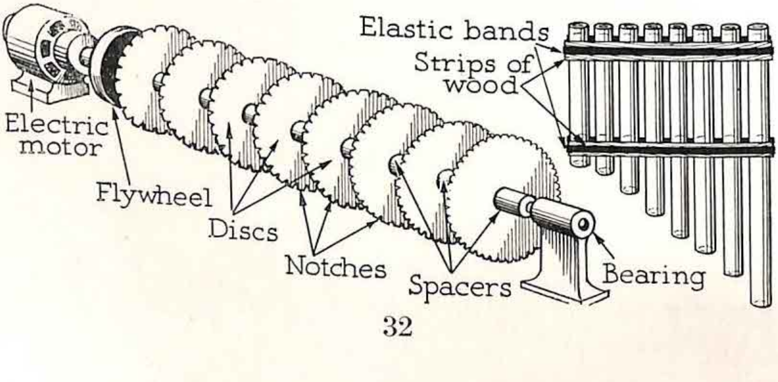
People who use hearing aids realize that they are only aids and do not reproduce perfectly all the sounds of speech. They can follow conversation much more easily if they can lip read as well so that their eyes and ears work together.

SOME THINGS FOR THE SCIENCE CLUB TO DO

(1) *Musical discs*

Mount on the axle of a constant-speed electric motor a heavy flywheel and eight circular rigid metal discs

FIGURE 33.



of equal diameter. Put spacers between the discs to keep them half an inch apart. Arrange a bearing at the end of the axle so that the whole axle spins evenly. (See Figure 33.)

Use a triangular file to cut notches around the circumference of the discs. Make sure that these notches are equally spaced around the circumferences. Mark their positions carefully before you start to file. There should be 24, 27, 30, 32, 36, 40, 45 and 48 notches respectively on the eight discs.

If you touch the edges of a disc with a card when the electric motor is running smoothly you will obtain a steady musical note. With a little practice you will be able to play simple tunes with the notes of the common musical scale produced by using all the discs.

(2) *Musical pipes*

Cut off eight lengths of glass tubing—the shortest being 4 inches long and the longest 8 inches. Calculate carefully the lengths of these eight tubes making them in these ratios.

$$1 : \tfrac{16}{15} : \tfrac{6}{5} : \tfrac{4}{3} : \tfrac{3}{2} : \tfrac{8}{5} : \tfrac{16}{9} : 2$$

Doh Ray Me Fah Soh Lah Te Doh

Heat the ends of the tubes quickly in a bunsen flame to take off the sharp cutting edges.

Blow across one end of a tube and you will produce a note due to the movement of the air in the tube. Close the other end and you will raise its note by one octave.

Arrange these pipes to give the tonic scale like the "Pipes of Pan" as in Figure 33. Learn to play simple tunes on these pipes. You should find it fairly easy to play the well-known plantation song called "Old Folks At Home."

Problem B: WHAT PART DOES LIGHT PLAY IN COMMUNICATION?

You have already learned that light is a form of energy. You recall that the light from the sun warms the earth and enables green plants to manufacture food. It is concerned in bringing the rain which is so necessary for life. In addition to these uses, there is another of great importance to everyone. It is light that enables us to see. So light is one of the chief means by which people communicate with each other.

The familiar "Stop" and "Go" signs along our roads tell motorists what to do and when to do it. Electric signs give all sorts of directions, warnings, and information. The beams of light from lighthouses and beacons help to guide ships at sea and planes in the air.

You probably know other such uses of light, but by far the most common mode of communication is by means of writing, printing, and pictures. In these cases also, light is needed, for of what value to you are written messages and printed material if you are in a perfectly dark room? In this problem we will learn how it is that a printed page can convey a message to our eye and brain.

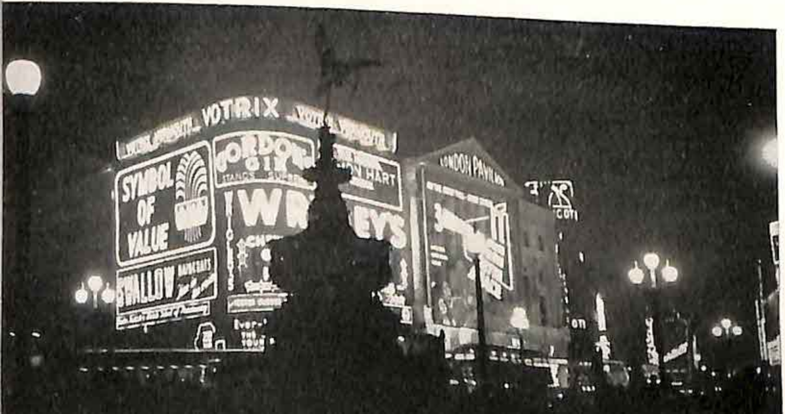


FIGURE 34. Piccadilly Circus, London.

Fox Photos Ltd.

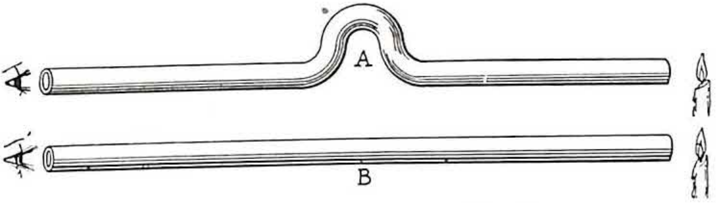


FIGURE 35. We see in straight lines.

Problem B: What part does Light play in Communication?

Question I. **How does Light form a Picture?**

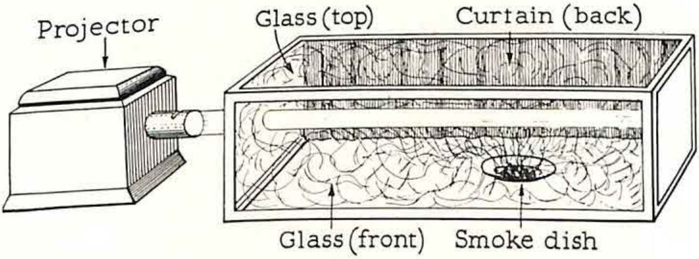
If you were asked why a squirrel is lost to sight when it goes behind a tree, you might well say that the tree hides the squirrel. Could you not go further and say that the light needed to see the squirrel did not pass through the tree or travel around it?

If you try to view a candle through a bent tube as in Figure 35A, you will not be able to do so, but if you straighten out the tube (as in B), the flame comes into view. This shows that we see in straight lines, but does light usually travel in straight lines?

SOMETHING TO FIND OUT: *In what way does Light travel?*

Because it is difficult to study light in a room already filled with it, we shall make use of a "smoke box." A box about one foot square and two feet long is satisfactory. One face of the box should be made

FIGURE 36. A smoke box for studying light.



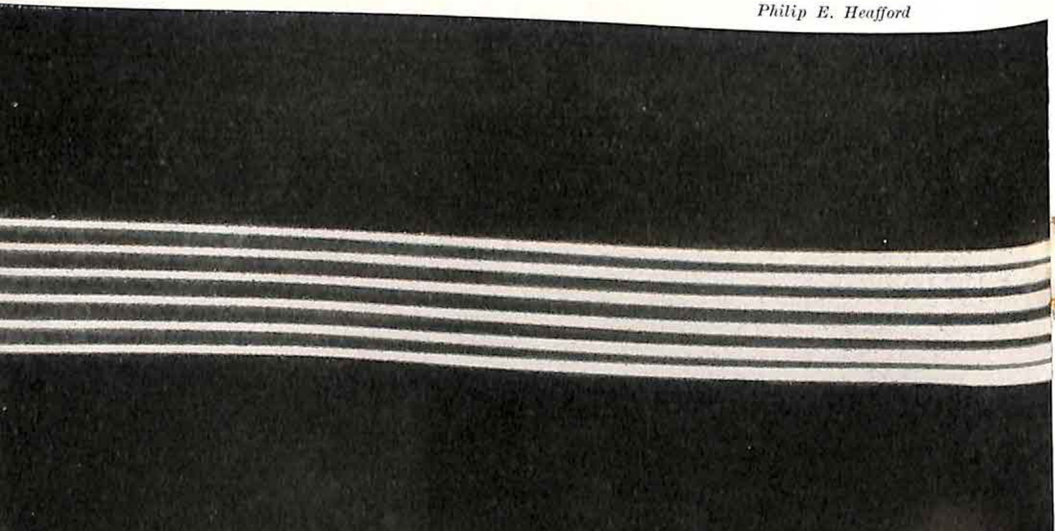
of a pane of glass or cellophane. A hole about one half inch in diameter should be made in one end as shown in Figure 36. A shallow dish containing smouldering paper or other suitable material is used to furnish the smoke. When light from a projector strikes the end of the box, some of the light will pass through the hole into the interior. As light travels through the air in the box, its path can be seen because it lights up the smoke. Figure 37 shows the paths of beams of light coming through six small holes in the end of a smoke box. Thus we see that light travels in straight lines.

If the projector were pointed slightly upward, which way would you expect to see the light travel in the box?

How must three pieces of cardboard with a small hole in each be arranged so that you could see an object through the holes?

FIGURE 37. Light beams travel in straight lines. Do you notice how the beams of light spread out a little as they go further away from the source of light on the left-hand side of the page?

Philip E. Heafford



SOMETHING ELSE TO FIND OUT : *Can Light, travelling in straight lines, produce a picture ?*

A "pinhole camera" can be made from a metal box, as shown in Figure 38. Such cameras can take real pictures, if film is used instead of tissue paper. You should be able to see the image of a lighted candle in the pinhole camera if the blinds of the room are drawn, or if you cover your head with a dark cloth.

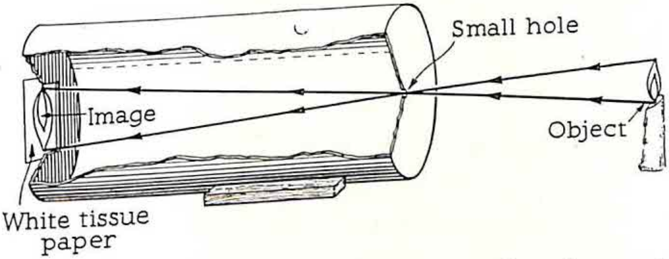


FIGURE 38. The image formed by light passing through a small hole is inverted.

Light from all parts of the flame streams toward the box. Some of this will pass through the hole. The light from the tip of the flame travels in a straight line to the lower part of the paper. That from the base of the flame goes straight to the upper part of the paper. Light from the other parts of the flame will fall between these beams and produce a complete image of the flame. Later you will see how images formed by light make it possible for men to communicate with each other.

If the candle were held upside down, how would its image appear ?

Was the image the same size as the candle flame ?

Why is the image so faint ?

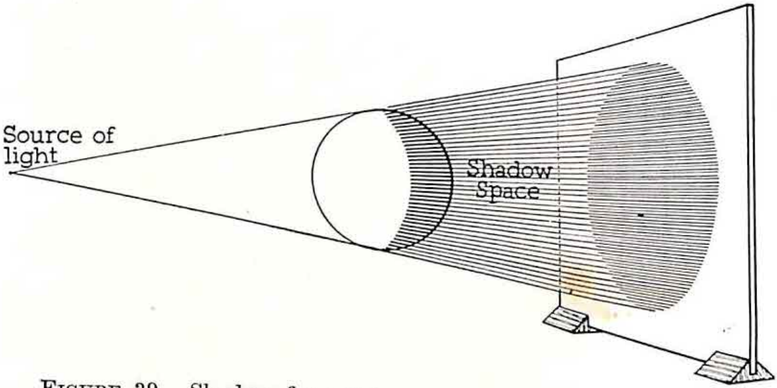


FIGURE 39. Shadow formed by a very small source of light.

Shadows are possible because light travels in straight lines. Everyone is familiar with shadows. Figure 39 shows how the shadow of a ball appears when the source of light is very small. Note that this one is dark to the very edge. When the source of light is large, as is that coming from an ordinary electric light bulb, the shadow is made up of two parts. There is a dark central portion called the *umbra* and also a partially dark area around it. The latter is called the *penumbra.*

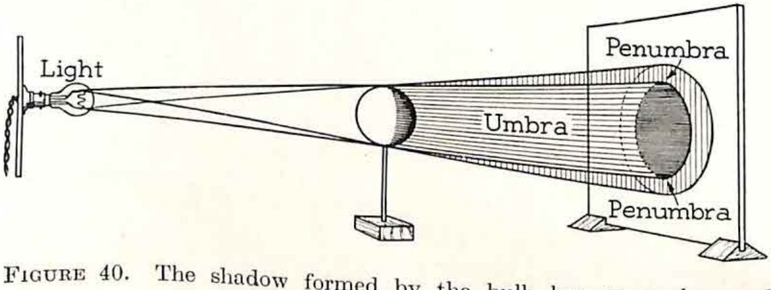


FIGURE 40. The shadow formed by the bulb has an umbra and a penumbra.

Figure 40 shows why these two regions are formed. No light reaches the umbra; some of the light but not all of it reaches the penumbra. Do you now see why some shadows are more distinct than others?

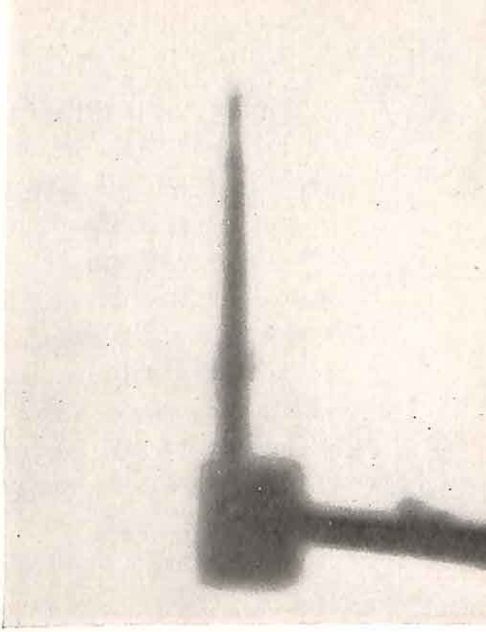


FIGURE 41. The hazy margin of the shadow of the pen held in a clamp is the penumbra. The central black portion is the umbra.

Eclipse of the Sun

The part of the earth which is in the umbra sees a total eclipse of the sun, whilst that in the penumbra sees a partial eclipse.

FIGURE 42. Eclipse of the Sun. The sizes and the distances of the sun and the moon have been changed to make the drawing clear.

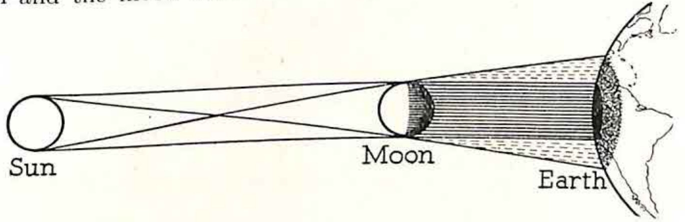
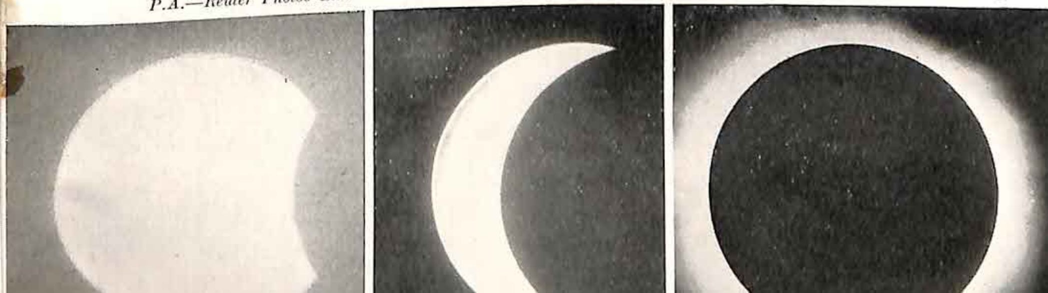


FIGURE 43. Photographs taken of the eclipse of the sun on 30th June 1954: (*a*) the moon begins to obscure the sun; (*b*) about three-quarters of the solar disc is obscured; (*c*) the moon completely hides the sun's surface making visible for a few minutes only the corona of flames.

P.A.—Reuter Photos Ltd. *P.A.—Reuter Photos Ltd.* *Picture Post Library*



It may happen that about two weeks before or after an eclipse of the sun there is an eclipse of the moon. Why is this ? Why are there more frequently eclipses of the moon than of the sun ? Look up in an almanac the details of an eclipse of the moon and calculate how long it takes for the moon to pass through the penumbra and through the umbra. Compare this with the time of a partial and a total eclipse of the sun.

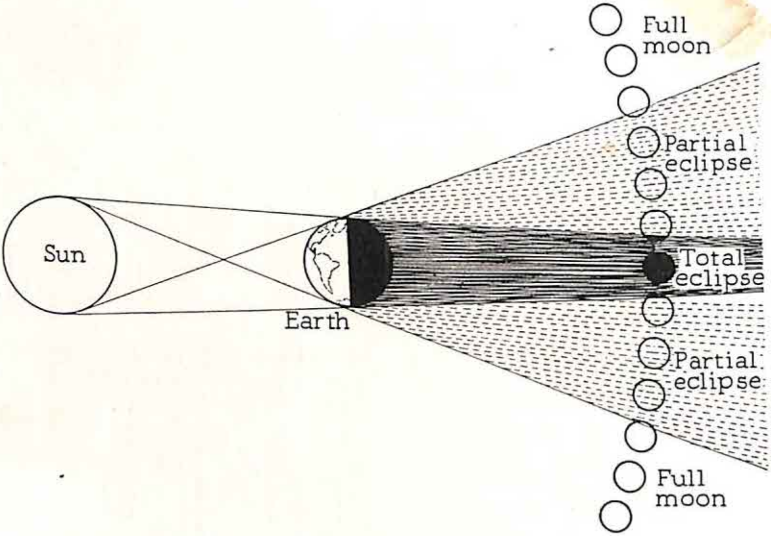


FIGURE 44. Eclipse of the moon.

Eclipse of the Moon

Do you think the size of the sun in Figure 44 is correct ? How should this be drawn ?

Look up the dates and the times of the eclipses of the sun (if any) and the moon during this year. Are they visible in your area ?

Question 2. **How does a Mirror form an Image ?**

You have seen that it is possible for light to form an inverted image if you cause it to pass through a small hole. You are much more familiar with the erect images formed by mirrors. Mirrors have many uses. You see them in homes, shops, cars and handbags. Then, too, you may have observed your dentist or doctor or oculist using a mirror in his work. Scientists find many things to do with mirrors of various kinds.

In the case of the inverted image you found that it was formed by the light which came from the object. But you know that light does not come from most of the objects which appear in a mirror. How, then, are these images formed ?

When light falls on your handkerchief, obviously it is reflected in all directions, because you can see the handkerchief no matter where you hold it before the eyes. Does a mirror scatter light in the same manner ?

SOMETHING TO FIND OUT : *Is Light reflected regularly by a mirror ?*

If a mirror is placed in a smoke box like the one in Figure 36, you can see how the light behaves as it strikes the glass. If the light is bright, and if there

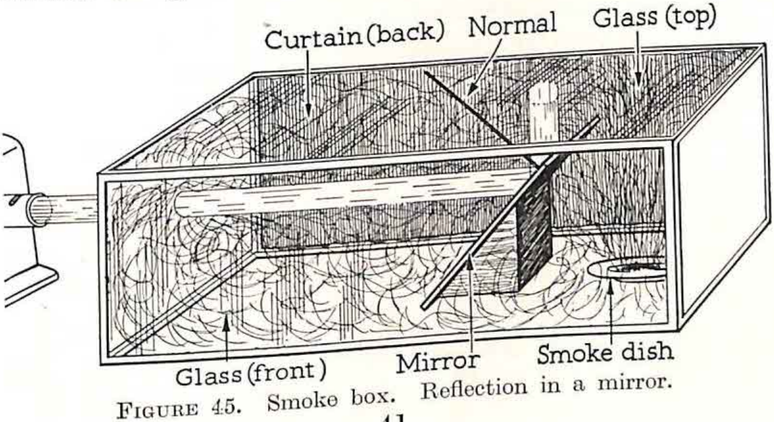


FIGURE 45. Smoke box. Reflection in a mirror.

is enough smoke, you can see the way the light travels after it is reflected.

If there were no smoke in the box where would you have to place the eye in order to see the reflected light?

Where would the light appear to come from?

Would the eye tell you that it actually came from the hole at the left of the mirror?

Figure 45 shows one such beam of light before and after it strikes the mirror. Draw a line at right angles to the mirror at the point where the beam is reflected by the mirror. This line is called the "normal" to the mirror. You can see then that the beam of light is regularly reflected. Measure the angles on either side of the normal and see if they are the same. One is called the angle of *incidence* and the other the angle of *reflection*. If you then turn the mirror in one direction or the other you will see that the reflected beam of light moves in the same way but through twice the angle.

IMAGES IN MIRRORS

Light reflected from a mirror can form an image. In your experiment using the smoke box only part of the light from the source was allowed to fall upon the mirror. Figure 47 shows what occurs when light from all parts of an object falls upon a mirror.

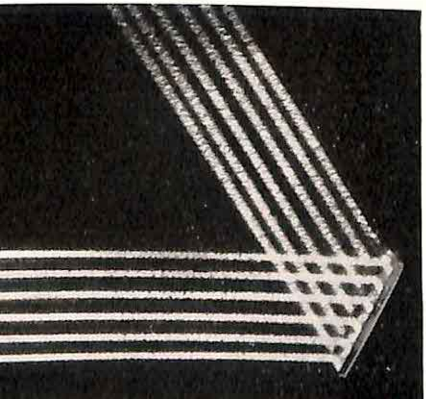


FIGURE 46. Six parallel beams of light reflected from the surface of a plane mirror. The light enters from the left and after reflection travels as six parallel beams in another direction. Copy the diagram, using a different colour crayon for each beam. Has the mirror caused the beams to change places when looked at along their lines of travel?

Philip E. Heafford

To make this clear, only a small portion of the light will be considered at first. The figure shows two rays leaving the very tip of the candle flame. Note that each of the rays is reflected and that they are separating as they travel. Since we see in straight lines the reflected rays will appear to come from the image behind the mirror.

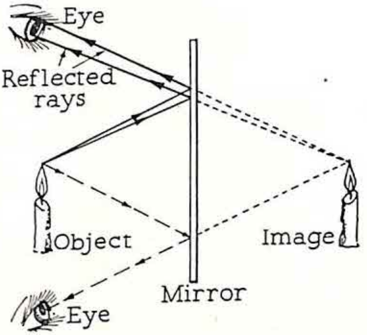


FIGURE 47. Why the image seen in a mirror appears behind it. Because we see in straight lines we think the light comes from the image. Draw the rays from the base of the candle.

Similarly, any other ray which starts from the object will appear to come from the image; for example, the one shown by the dashes, which enters an eye at the bottom of the diagram. Since every other point of the object will send out light which the mirror will relay to the eye, the mirror may be said to form a complete image of the object. In this figure you can see both the object and the image. If you measure the distances in Figure 47 you will discover that the image of the object is the same distance from the mirror as the object itself is. Can you prove that this must be so? Also measure the angles.

If the object were behind you, so that light from it could not enter your eye, you would see only its image in the mirror. This is the case when a motorist views traffic behind his car in the mirror before him.

Mirror images are not exactly like the object. Because the image is erect, of the same size and as far from the mirror as the object, the image appears very real. You know, however, that it is an optical illusion; that no

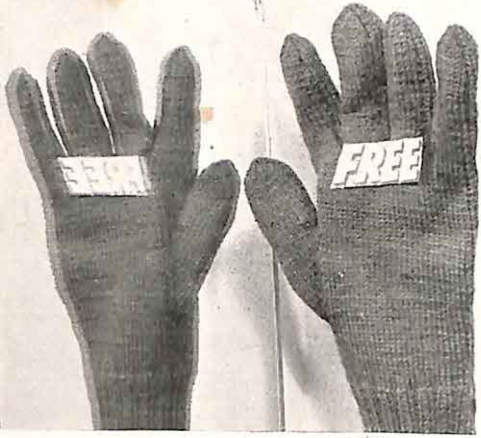


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FIGURE 48. The image of a left-hand glove looks like a glove for the right hand.

light starts from the image seen in the mirror. Figure 48 shows that the image is like the object except that it is reversed. The object is a *left*-hand glove in front of the mirror. The image seen in the mirror is exactly like a glove for the *right* hand.

This turning about of the image usually does no harm, but printed matter " reads backwards ", as you can see. Can you tell the time from the mirror image of a clock face ?

SOME THINGS YOU MAY CARE TO DO

1. Take two plane mirrors and use them to look at the side of your face. What is the angle between the two mirrors in this position ?

2. Place the mirrors at right angles to one another and close together. What do you notice about the middle image of the three images ?

3. On a large sheet of white paper place two long but narrow mirrors, at right angles, in the centre of the paper, their fronts touching one another. Put something in this space and mark the position of the images you can see. You should move your head about slowly and point at the images with a long pencil. Where are these images precisely ?

4. Repeat this with the mirrors at sixty degrees. Draw on the paper a design or put little pieces of coloured paper or beads into the space. Try to make an attractive pattern. Your pattern will be brighter

if you use a strong light and if the two mirrors are made of thin glass. Why is this?

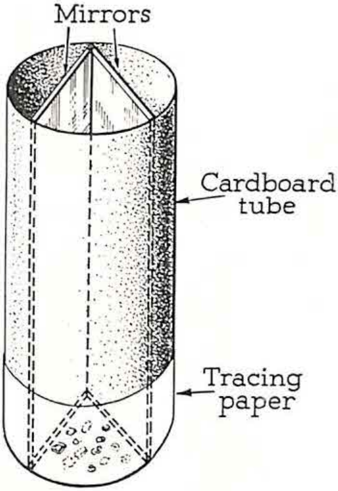

Figure 49. Kaleidoscope.

5. Make for yourself a kaleidoscope as in the figure, using two long thin mirrors and pieces of broken coloured glass and beads. You must be very careful to fix your mirrors exactly at sixty degrees. Why is this?

6. Erect two large mirrors parallel to one another, and put something between them. How many times can you see this thing now? Can you draw the way the light is reflected from the mirrors to form these images?

Curved mirrors are useful. The difference between the images formed by the back and front surfaces of a spoon can be interestingly shown by holding the point of a lead pencil about a quarter of an inch from each of the surfaces. *Do not fail to try this experiment.* You will find that the back of the spoon forms an image smaller than the object, while the front produces a larger one. Shaving mirrors are often slightly curved so that the face appears somewhat enlarged. How are they curved? Their surface is concave and the mirrors are called concave surfaced mirrors or simply concave mirrors. The

Figure 50. Circular convex mirror of a motor car showing traffic behind.
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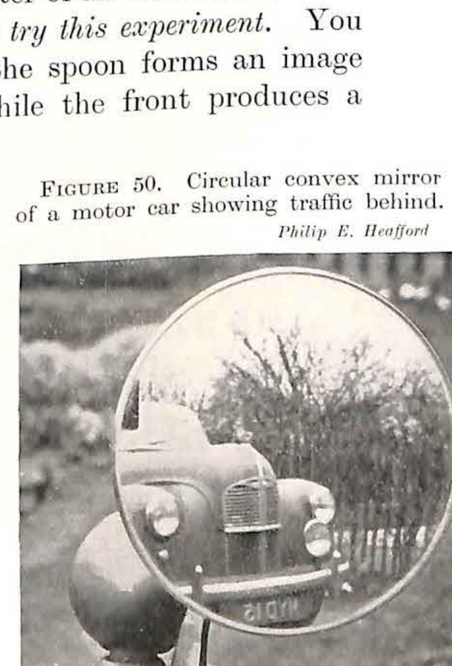


mirror used on the wing of a car is curved like the back of the spoon and thus gives small images of large objects. This is a convex mirror. The driver can get a clear view both of the road and of the cars behind his own because his mirror " covers " a wide field. Some of our largest telescopes have curved mirrors to form images of the planets and the stars.

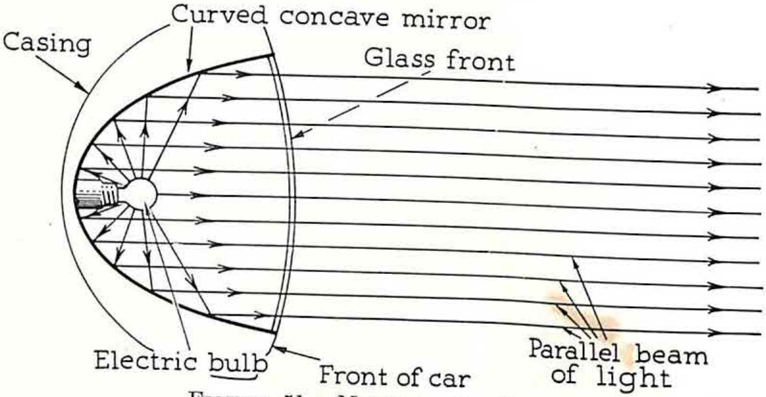


FIGURE 51. Motor car headlamp.

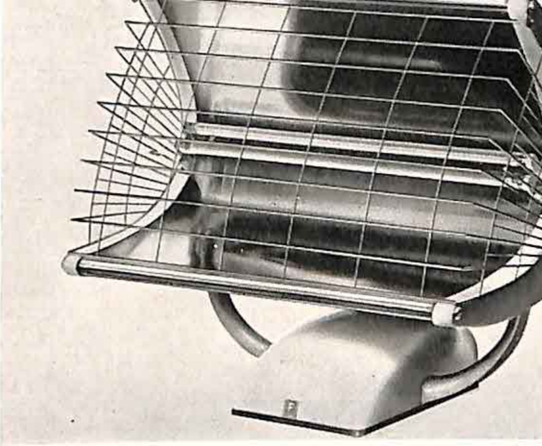
There is a mirror inside a motor car headlamp. Figure 51 shows how the light that is emitted by the electric bulb is reflected in a forward direction from the curved concave surface. Nearly all the light is projected forward in a parallel beam to give a strong light on the road ahead. *Is this mirror part of a sphere? Where is the electric bulb placed?*

SOME THINGS YOU MAY CARE TO DO

1. Obtain a large concave mirror and point it towards the sun on a hot day. Find a place where the sun's rays are concentrated after reflection. This spot will be somewhere in front of the mirror, according to how deeply the mirror is curved. Put your hand there. Does it get hot? Try heating some water in a small black can placed at the spot.

2. Examine an electric reflector fire. Write an account to explain why this fire throws heat forward in a beam.

3. Copy precisely the curve of the reflector of an electric fire, and the position of the bar on a large sheet of paper. Then draw the track of the heat rays.



Courtesy, Ferranti Lt

FIGURE 52. An electric reflector fire.

Problem B : What part does Light play in Communication ?

Question 3. **How does a Lens form an Image ?**

In our study of mirrors you have found that the images are formed by reflected light. You are also familiar with the images formed by the common magnifying glass. In this case the glass is between the object viewed and the eye. Thus you may be sure the light passes through the glass. Pieces of glass so shaped that they may be used to form images are called *lenses*. Eyeglasses represent a very common use of lenses. Some of them are thicker at the centre than at the edge, while others are thicker at the edge. In order to understand how a lens may form an image you will need to do two very interesting experiments.

SOMETHING TO FIND OUT : *Can an image be formed on a piece of paper by a lens ?*

For this experiment a lighted candle makes a good source of light. A lens which is thicker at the centre than at the edge (a converging lens) should be fastened or held over a hole in a large cardboard. The cardboard is first placed near the burning candle (six inches

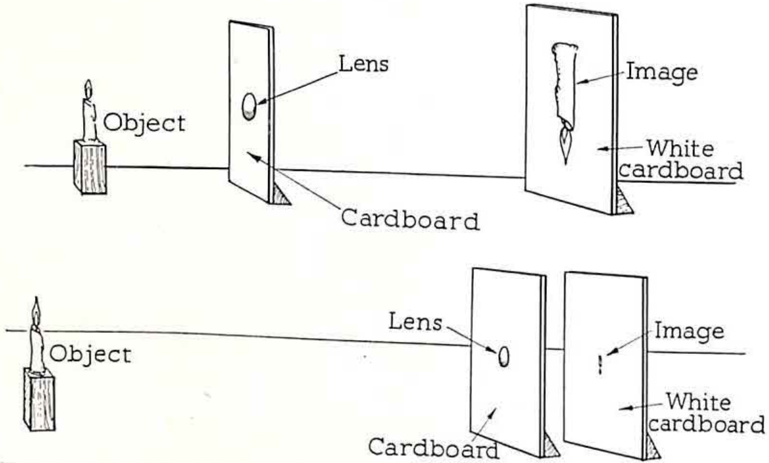


FIGURE 53. How to show the images formed by lenses on a cardboard. Do the images appear the right way up or upside down ?

away will probably be satisfactory). The second white cardboard or piece of white paper is then moved backwards and forwards until the image of the candle is clear. Figure 53 shows the arrangement of the apparatus.

Next move the candle to a distance from the lens, say four or five feet. Bring the paper toward the lens until the image is again clear. If the room is even slightly darkened, you should be able to see the image of the flame flicker just as the candle flame does. Light which started from the object really comes to the eye from the image. It is often called a real image.

Compare the real image formed by the lens with the image formed by a mirror : (a) as to size ; (b) as to position.

Would the lens you used form a large or a small image of a tree outside your class-room ?

Would the image of the tree be formed close to or far from the lens ?

Figure 54 is a photograph of six separated light beams which were made to pass through a lens. In this case the lens was thicker at the centre than at the edge. The lens used in Figure 55 was thicker at the edge than at the centre. In each experiment light was allowed to strike the lens at six places. Figures 56 and 57 show that the lenses bent all the light that fell upon them in the same manner as the six beams were bent.

If you want to record your observations in the way the scientist does, then you will want to know how to describe lenses and mirrors correctly. The lens used in the lighted candle experiment in Figure 53 and in Figures 54 and 56 is a *converging* lens which usually has two *convex* surfaces. This lens is thicker at the centre than at the edge.

The other type of lens shown in use in Figures 55 and 57 is a *diverging* lens which usually has two

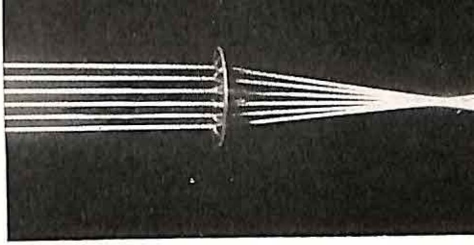


FIGURE 54. Bending of light by a converging lens.

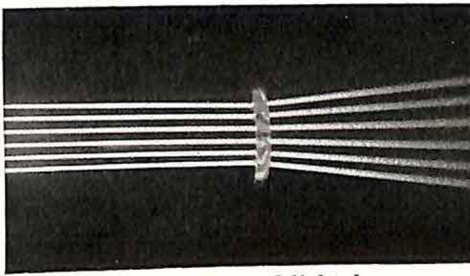


FIGURE 55. Bending of light by a diverging lens.

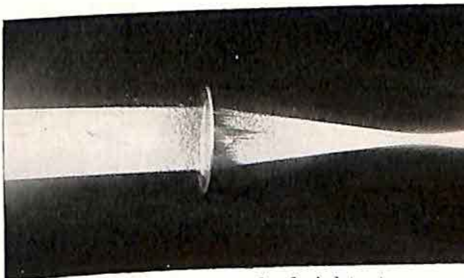
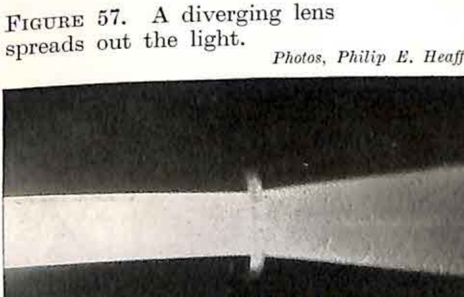


FIGURE 56. Where is the brightest place in the light beams bent by a converging lens?

FIGURE 57. A diverging lens spreads out the light.

Photos, Philip E. Heaf



concave surfaces. This lens is thicker at the edge than at the centre.

So a converging lens converges a straight or parallel beam of light to some small spot of light, whilst a diverging lens causes the parallel beam of light to spread out as if the beam had started from a single small source.

What kind of lens is used for a camera?

What kind of mirror is used in (a) a floodlight, (b) at a street corner to enable a driver to see what traffic is coming?

IMAGES DUE TO LENSES

The image formed by a lens is always inverted. During your experiments on page 48 you found that the images formed were turned upside down or *inverted* in both cases. Further experiments would show you that images formed on a screen are always inverted. Why this is true is best shown by Figure 58. To make it simple, only three rays of light will be used from each end of the object. Of course all the rays that start out from the tip will come together to form the image of the tip. The dotted lines show three rays leaving the base of the candle. In most cases this inversion of the image does no harm, for we can invert the object and thus get an *erect* image, i.e. the right way up, on the screen.

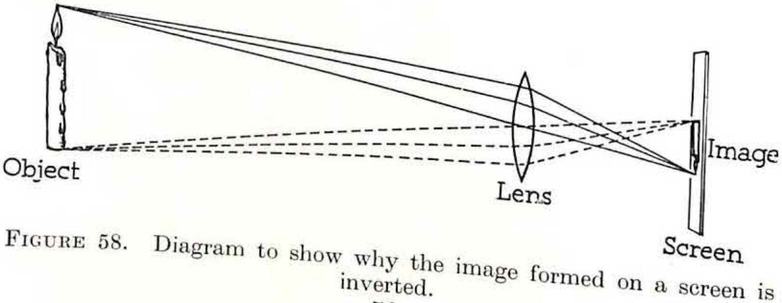
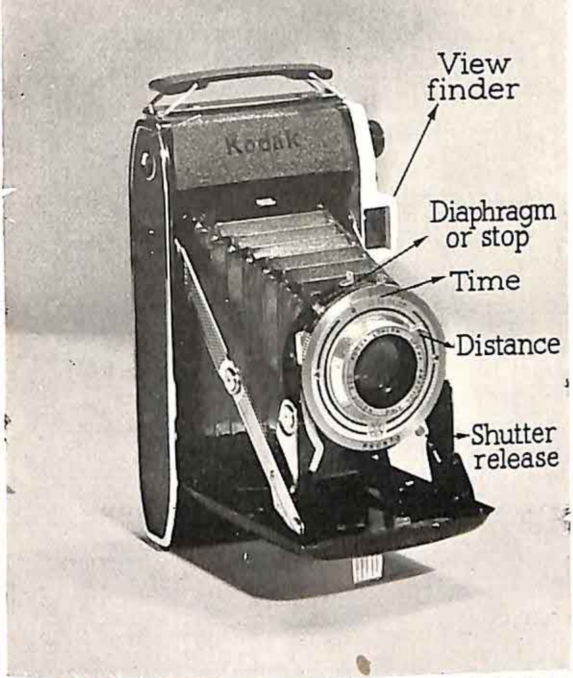


FIGURE 58. Diagram to show why the image formed on a screen is inverted.



Courtesy, Kodak Ltd.

FIGURE 59. A modern roll film folding camera.

The photographic camera. This optical device uses a converging lens to form an image of an object on a light-sensitive film. The lens is usually mounted in such a way that it can be moved back and forth to "focus" the image clearly and sharply on the film. A scale of distances is prepared so that this can be done accurately and quickly. A "stop" or iris diaphragm is fitted close to the lens to cut out the light from the edges of the lens. Light passing through the edge of the lens does not form such a sharp image as that passing through the centre. This diaphragm varies in size to control the amount of light you require to enter through the lens in order to "expose" the film. Behind the "stop" there is a shutter that can open for a certain length of time. The time may vary from one to one hundredth of a second according to the setting of a small lever. This is called the time of exposure.

The camera is pointed towards the object to be photographed; the lens is adjusted to give a sharp image; the "stop" and the time of exposure are adjusted together to give the correct amount of light for your film; then the camera is held very steady and the shutter is operated. The film is taken out in darkness

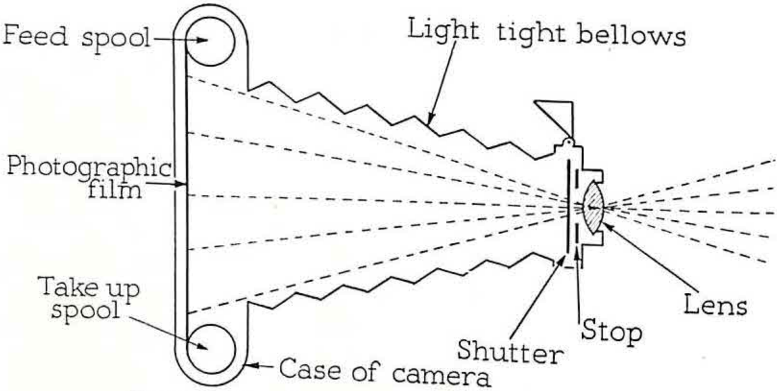
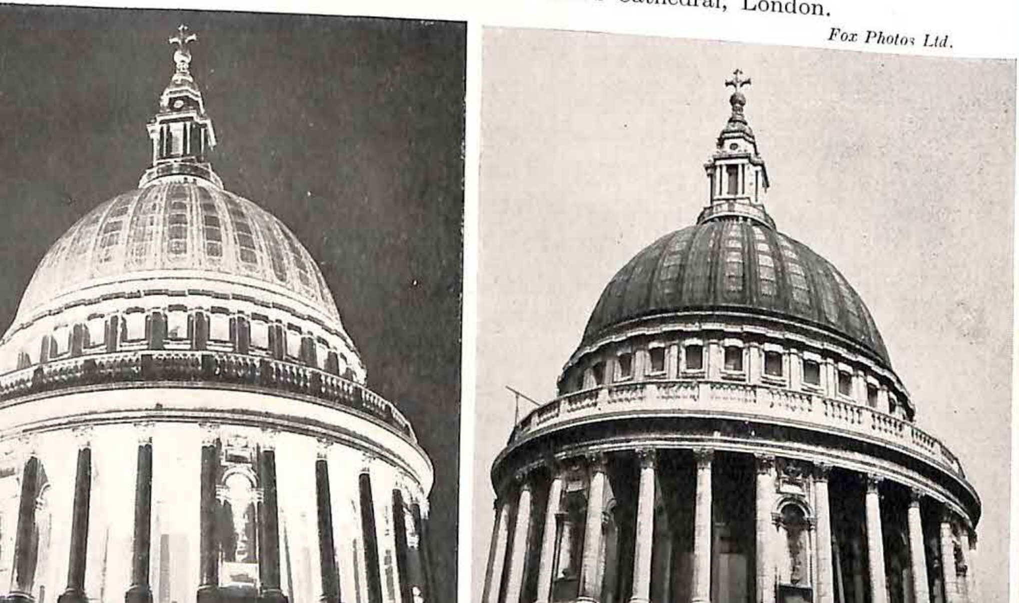


FIGURE 60. The essential parts of a camera.

and "developed" in certain chemical solutions in order to make the image permanent and visible. The light parts of the object appear dark on this film and the dark parts of the object appear light. Thus the film is now called a "negative". This negative is then placed against the active surface of some sensitive photographic paper and light is allowed to shine through the negative on to the paper. The paper is then "developed" in exactly the same way as the film. The result is a "positive". Figure 61 shows a negative on the left and a positive made from it on the right.

FIGURE 61. The Dome of St. Paul's Cathedral, London.

Fox Photos Ltd.



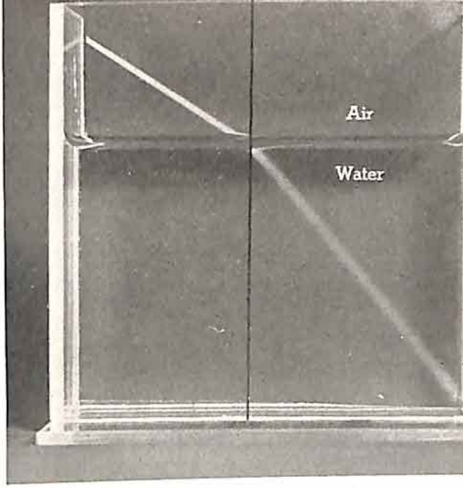


FIGURE 62. The light is bent just as it enters the water.

Light is bent as it enters or leaves a substance. A glance at the photograph showing a beam of light entering water (Figure 62) will show you that its path is straight both before and after it entered the fluid. The bending took place just as the light passes from the air into the water. If the light had started in the water, it would have been bent just as it came out into the air. In the case of a lens, the light is bent twice: once as it enters and again as it leaves the glass.

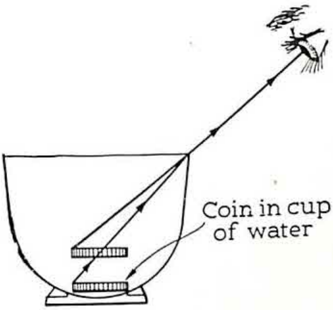


FIGURE 63. Coin in cup of water.

An easy experiment to show the effect of bending can be done at home by using a coin placed on the bottom of an empty cup. If you hold your eye so low that you cannot see the coin over the edge of the cup and then pour water into the cup, the coin becomes visible. Figure 63 shows the path of the light and the apparent position of the coin.

SOMETHING YOU MAY CARE TO DO

1. Make for yourself a beam of light. The best way is to use a motor-car head-lamp bulb which has a straight filament and then mount it inside a tin can so that the filament is parallel to a slit in the side of the

can. If the slit is a narrow one then you will obtain a clear narrow beam of light. Pass this beam through a block of glass resting on a sheet of white paper. Sketch the many different courses that the light takes as it strikes the block at different angles. Can you arrange the block so that the light in trying to come out again into the air is actually reflected in again ?

What do you think a fish can see as it looks up towards the surface of a pond ? Can you draw this ?

Pass the beam of light through a glass prism. What do you notice about the light as it emerges ? Draw this carefully.

2. Can you follow the track of a ray of light by a series of pins ? Set up a block of glass and a prism of glass on a sheet of white paper and trace a ray of light through them by sticking pins into the paper so that the pins appear to be in a straight line. A number of pins will appear to be in a straight line if you look along them and can see them all one after the next, even if the actual ray that they follow has been bent at several places. You will notice the same bending taking place as in the last experiment you did. In the case of the prism measure the angle through which the ray bends as it passes through the whole prism. *Does this vary for each position ?* Measure all the angles in the case of the ray which has the least bending. *Do some of the pins appear coloured ? If so, which ones ?*

SOME THINGS TO THINK ABOUT

1. Need the image of a man six feet tall be exactly six feet high on a cinema screen ?

2. Why do pools of water appear more shallow than they really are ?

3. Why is the real image of the sun so small and so hot ?

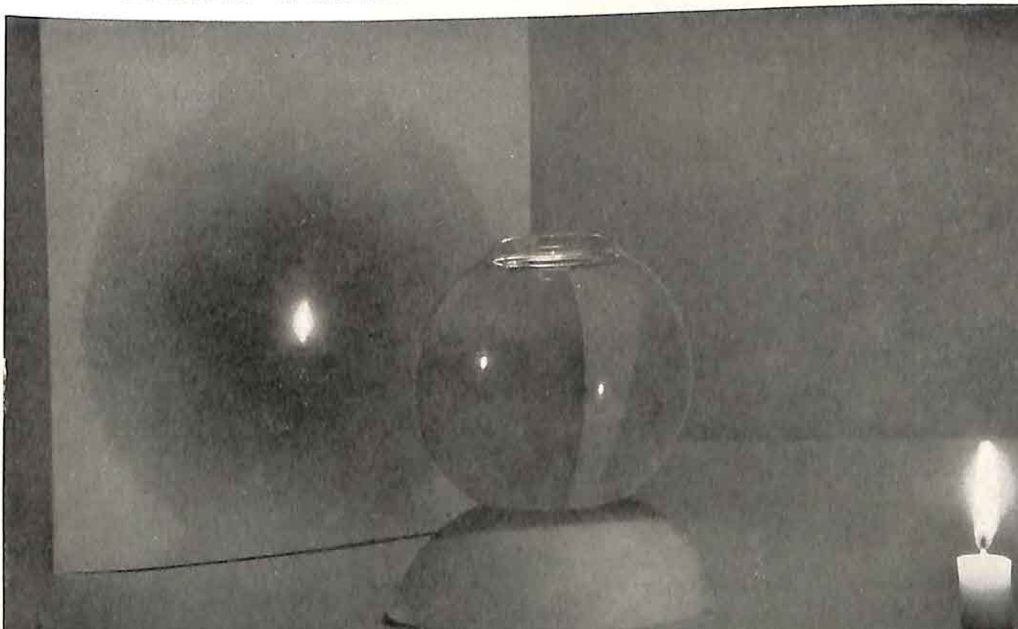
Question 4. **How do we See ?**

You have seen how images are formed, but these images must be carried to the brain if they are to help us to communicate with each other. Most of our common pictures are made by the use of lenses. A camera is simply a light-tight box with a lens in one end. The image is formed on a film which is coated with chemicals. This image can be made permanent by developing and fixing in special solutions. The eye is sometimes called " our most wonderful camera." By studying an eye you can see its likeness to a camera.

SOMETHING TO FIND OUT : *Can a convex body of water be used as a lens ?*

If you hold a small fish globe between a lighted candle and a piece of white paper, you will find that the globe does not form an image of the light on the paper. If, however, the globe is filled with water and used as shown in Figure 64, a bright image of the light can be seen if the paper is at the proper distance from

FIGURE 64. A fish bowl filled with water may be used as a lens.



the globe. To find this position, place the paper against the globe and then move it slowly away until a distinct image appears.

In like manner images can be formed by a lens made of a jelly-like substance. A gelatine lens, for example, can be made by allowing a solution of clear gelatine to harden in a watch glass or dish of similar shape.

Is the image erect or inverted?

In your trial was the image the same size as the object?

SOMETHING ELSE TO FIND OUT: *Can the lens of an eye form an image?*

From the butcher you can get the eye of a pig or a bullock. Cut this open carefully with a very sharp penknife. Inside, you will find a rather soft piece of matter which looks like glass. It is easily recognized as a lens with two convex surfaces. If you drop it into a tumbler of water you will see how it takes the shape of a regular smooth lens. By pressing it gently between your fingers in the water you can make it vary its thickness in the centre. So this lens can be made very converging or less converging but you will note it is always a converging lens.

It is easy to show that such a lens will form very good images. Place it in a small depression made in a block of paraffin wax. Next put the wax block and lens about two feet from an electric light bulb or a lamp and obtain a clear image of the light on a piece of white paper.

Being careful not to move either the wax block or the paper, move the bulb closer to the lens. The image will now be less distinct, but if you press gently upon the top of the lens so as to make it thicker, you can make the image become clear again (see Figure 65). If you are successful, you will have shown that a

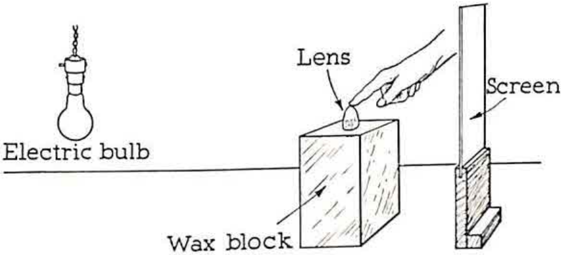


FIGURE 65. To show the effect of making the lens of an eye thicker.

flexible lens can produce clear images of objects at various distances from the lens.

The tiny image of a window of your room, if formed on white paper by the lens from the eye, is often very beautiful, especially if plants or trees are in view.

Is the image erect or inverted?

Does making the lens thicker produce an image of something nearer, or farther away?

Simple Magnifying Glass or Reading Glass

Figure 66 shows the manner in which a converging lens is mounted and used by watch repairers in examining and adjusting the small parts of a watch or clock. Large lenses of this kind are also used as reading glasses. The boy is using one to look at detail in his stamps. In both cases the object to be viewed is near to the lens and the image is the right way up and much larger. Can you follow how the rays of light are bent as they pass through the lens? Notice that

FIGURE 66. Using an eyeglass to adjust a watch.

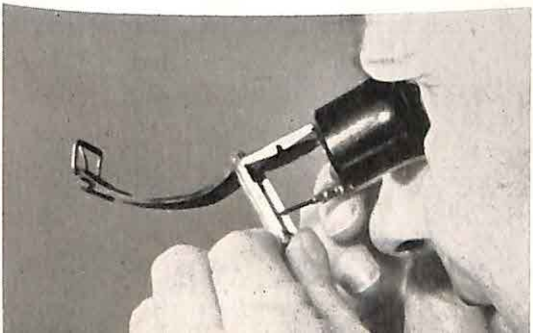


FIGURE 67. A boy using a magnifying glass to examine his collection of stamps.

Photos, Philip E. Heafford

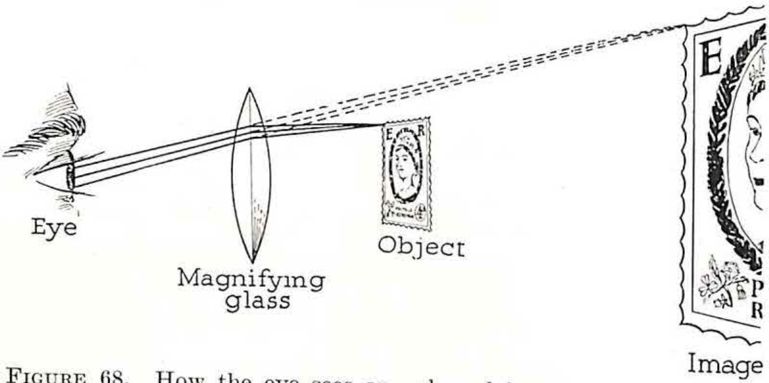


FIGURE 68. How the eye sees an enlarged image of a small object with a magnifying glass.

the observer imagines the light has been travelling in a different direction, and from a different and much bigger object. How eyes can be deceived!

SOME THINGS YOU MAY CARE TO DO

1. Use a magnifying glass to look at the image of a distant object formed by a large weak converging lens. Mount both lenses on a rod and you will have made a telescope. Describe the image you see and use it to look at a distant brick wall. What is its magnifying power?

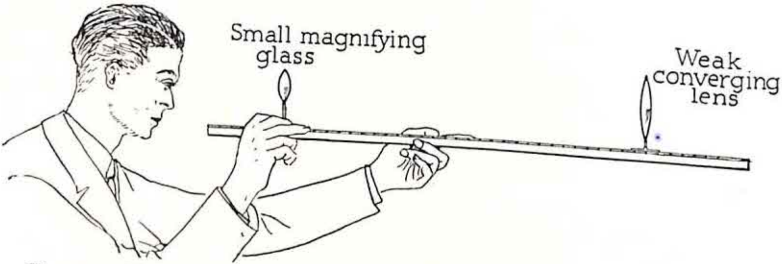


FIGURE 69. How to make a telescope with two simple lenses.

2. Use the same magnifying glass to look at the image of a very near object formed by a small strong

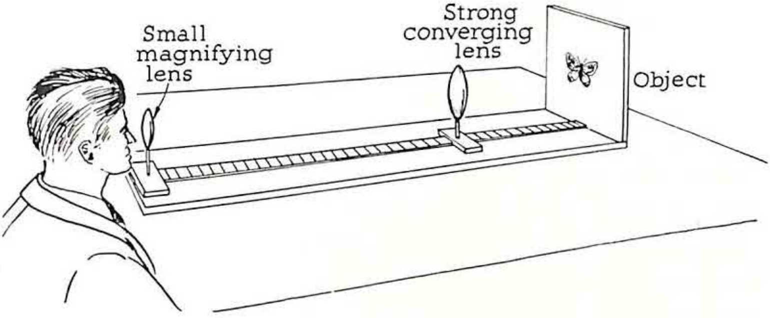


FIGURE 70. How to make a microscope with two simple lenses.

converging lens. If you choose your lenses properly, you will get a greatly enlarged image. This will be a microscope.

OUR EYES

The eye is like a camera. An examination of the human eye diagram (Figure 71) shows that the lens is in the front portion of a ball-shaped cavity which corresponds to the box of a camera. The image is thrown upon a layer of nerve endings at the back of the eyeball, called the *retina*. As in the camera, the image formed by the lens is inverted, but the effect carried to the brain is such that the object appears upright. The retina cannot be moved back and forth but the eye is supplied with muscles which make the lens thicker or thinner. This serves to focus good images on the retina except when objects are too close to the eye. If you hold this book only three inches from your eyes, you cannot see the print distinctly.

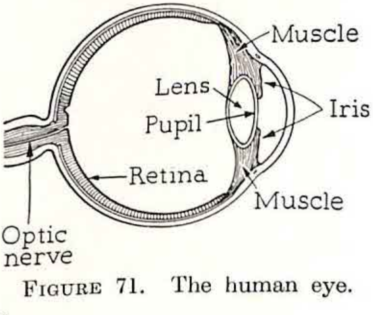


FIGURE 71. The human eye.

You are already familiar with the fact that the amount of light let into some cameras can be altered by varying the size of the "stop" or hole placed near the lens. The amount of light admitted to the eye is also regulated by the size of the "window of the eye." This window is a hole in a thin sheet of muscular tissue called the *iris*. The pupil (hole) becomes smaller when the light is bright, but opens wider when the light is dim.

You can easily observe the change in the size of the pupil of your own eye at home. Simply cover one eye with your hand for about three minutes and then look at both eyes in a mirror. How long did the pupil remain enlarged after you removed your hand ?

If you live in the country away from bright lights of all kinds, you will have noticed the vast number of stars in the sky. The same stars are there for the city dweller to see, but he must allow time for his pupils to open wide enough to see them all. This happens after about 50 minutes of complete darkness during which he does not look at any bright light. Then he will be able to see even the faintest stars.

Does a cat see more easily than we do in the dark ?

Have you noticed the shape of the pupil of a cat's eye ? What is its size in bright sunlight and also in a dimly lit room ?

Some defects of the eye can be remedied by glasses.

A *nearsighted* person cannot see distant objects distinctly. In this case the retina is too far away from the lens of the eye. The image falls in front of the retina instead of upon it. This condition is shown in Figure 72. The figure also shows how a diverging spectacle lens of correct strength diverges the light just a little so that the image is formed on the retina.

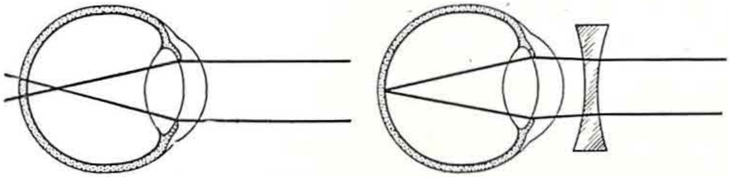


FIGURE 72. A nearsighted eye corrected by a diverging lens.

A *farsighted* person cannot see near-by objects distinctly. In a farsighted eye the distance between the lens and the retina is too short. In this case if an image was formed it would have to be outside the retina, as shown in Figure 73. The lens cannot change enough in shape to form the image on the retina. This defect can be remedied by using a converging spectacle lens of the correct strength.

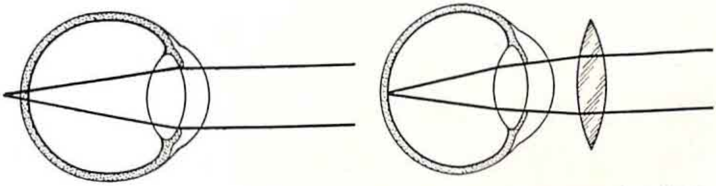


FIGURE 73. A farsighted eye corrected by a converging lens.

As people grow older, the lens of the eye may lose some of its flexibility and ability to accommodate itself to objects near and far. In this case people usually have two sets of spectacles: one for distant objects and the other for those near-by. Some people use bifocal lenses. A bifocal lens is really a combination of two lenses: one for distant and the other for near-by objects.

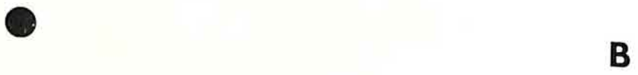
You should take good care of your eyes. Because your eyes are so essential to your safety, your comfort, your success in life, and many other things, you should be very careful not to injure them in any way. Some thoughtless people damage their eyes by reading in very dim or in very bright light. You should never look at the bright sun or read in bright sunlight. It is often desirable to protect your eyes against excessive light reflected from snow and the glare at the seashore. Even at home you can avoid undue fatigue by not reading too long at a time and by using a suitable lamp-shade.

Wear glasses by all means if you need them; your eyes are more important than your looks. If your eyes feel uncomfortable or if you do not see clearly, be sure to ask the advice of your doctor. You may not know that you do not see as well as your friends. You may need glasses even though your eyes do not seem to be giving trouble.

SOMETHING YOU MAY CARE TO DO

Where the optic nerve leaves the retina rays of light produce no effect at all. It is called the blind spot and is situated at the back of the eye slightly nearer to the nose.

Hold this book in your outstretched arm and look at the large black dot.



Move the book gradually nearer to your right eye keeping the left eye closed. You will notice that at some position the letter B will disappear. This will occur when the image of B falls upon the blind spot and the image of the large black dot is being seen most clearly at a place called the yellow spot. Can you think how to do this experiment with the left eye?

Problem C: **WHAT PART DOES COLOUR PLAY IN COMMUNICATION?**

How many of us realize what a great part colours have to play in controlling our lives. We stop and go at cross-roads according to the coloured instructions of the traffic lights. When we see the amber caution light we know that the next colour will be red, so we prepare to stop.

Our railway trains are guided on their way in perfect safety by various combinations of lights. Some say "Stop," others say "You may have to stop at the next signal, so be prepared."

Flashing lights of different colours guide aircraft over the countryside, red ones indicate tall buildings and dangerous obstacles, yellow ones show the pilot the direction of the runway in use, blue ones tell him where the dispersal bays and the perimeter tracks are laid out.

Ships of all nations obey colour navigation codes, flags of various shapes and colours spell out messages and warnings for all to see. At night the shipping lanes are kept open and free from collisions by the aid of the navigation lights of the vessels which travel therein.

Do you know the colours exhibited on the masthead, the starboard and port of a vessel at sea?

Can you form the distress signal in coloured flags?

Have you been attracted by the coloured advertisements in our streets? A special kind of paint is now used which glows with very bright colours in daylight.

Some colours blend well and we say they are in harmony, others clash and irritate us.

Question I. How do we get Coloured Lights from White Light ?

During the experiment on page 54 you passed a beam of light through a prism and noticed that the light split up into colours. Sir Isaac Newton, a famous English scientist, was the first man to do this experiment. He passed a narrow beam of sunlight from a slit in a window blind through a triangular glass prism. The beam split up to form a band of many colours which was caught on a white screen. This band of colours is called a spectrum and the actual colours all merge into one another.

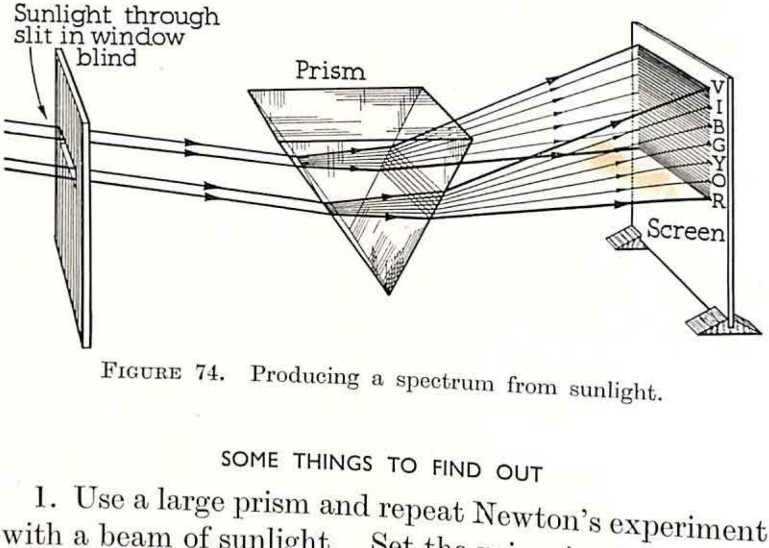


FIGURE 74. Producing a spectrum from sunlight.

SOME THINGS TO FIND OUT

1. Use a large prism and repeat Newton's experiment with a beam of sunlight. Set the prism in the position which gives the least bending of the light rays. *Which colour is bent least ? Which most ?* Name the colours red, orange, yellow, green, blue, indigo and violet.

2. Make a small spinning top with a circular card painted with these seven colours. Spin this rapidly in a bright light. Do these colours recombine to form white light ? You may have to try several times

before you get all the colours to balance correctly and even then the best you will have will be a dirty white. Why is this ?

White and black. From these experiments do you conclude that white is a mixture of all the colours ? What then is black ? Where no colour falls at all, is it black ?

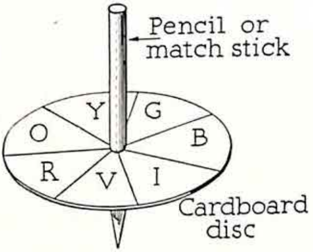


FIGURE 75. Colour spinning top.

Colours of solid things. All objects absorb some colours and reflect others. We say an object has a certain colour if we can see that it reflects that colour.

SOMETHING ELSE TO FIND OUT

Form a large and clear spectrum by passing through a prism the light from a slit in a slide placed in a projector. Do this in a well-darkened room and do not let white light get on to your screen. Place in the spectrum a white piece of paper. In the red part of the spectrum the paper appears red ; in the green it appears green, and in any other part of the spectrum it takes the colour of the light which falls upon it.

Hold a green or blue piece of paper in the red of the spectrum, no light is reflected. Does it appear black ? Does a red piece of paper appear black in the green or blue part of the spectrum ?

Would you agree that the colour of an object depends on two things : (1) the nature of the light which falls upon it and (2) its capacity to reflect the waves of that colour ?

If an object cannot reflect any of the light which it receives, but absorbs it all, is it black ?

Question 2. **What do we mean by Primary and Secondary Colours?**

Colours of transparent things. Only red light will pass through a piece of red glass or red gelatine whatever kind of light is presented to it. Similarly a green piece of gelatine will only transmit green and a blue piece only blue.

Primary colours. Red, green and blue are the three colours from which all other colours can be made. When two of these primary colours are mixed together, then a secondary colour is produced. Secondary colours are yellow formed from the red and green, magenta from the red and blue, and peacock blue from the blue and green primary colours. If your school has stage lighting, what colours are used for the filters in front of the lamps and how are they arranged?

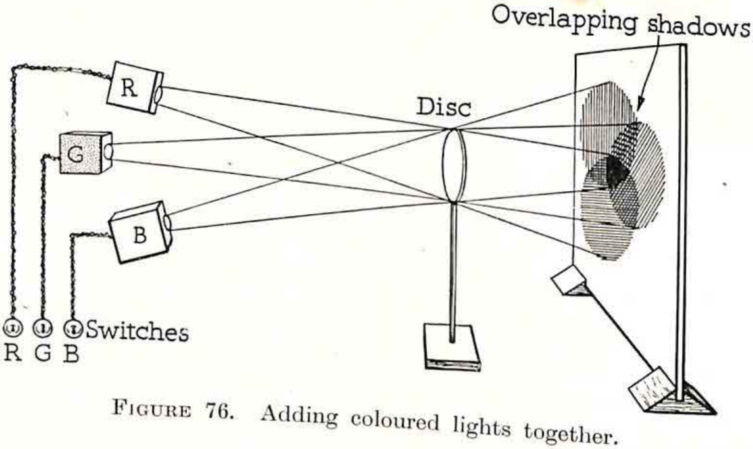


FIGURE 76. Adding coloured lights together.

SOMETHING TO FIND OUT

Allow the light from three lanterns or three lamps in biscuit boxes to fall upon a large white screen. In front of each of these three beams place a red, a green or a blue gelatine filter. Switch on only the red and the green lanterns. *What secondary colour does this produce? How are the other secondary colours produced?* Hold a circular disc so that it forms a shadow in all three beams of light. Examine carefully the colours of each section of the shadows and try to find out which lanterns illuminate each section. *What colour is seen where all three shadows overlap?* What colour surrounds all the shadow formations?

A colour triangle is shown in Figure 77. Can you see why the colours are arranged in these positions? *What colour should be in the centre of the triangle?* Two opposite colours are called complementary colours.

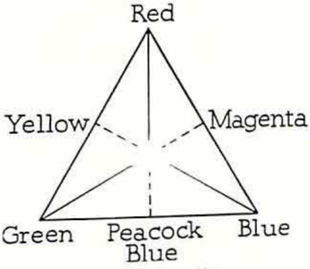


FIGURE 77.

SOME THINGS YOU MAY CARE TO DO

1. Stare at a single spot on a well-lit red cross on a white background and then, after say a minute, suddenly remove the red cross, leaving only the white background. What do you see? *How do you account for this strange result? Can you think of other similar changes to try?*

2. Cut a piece out of a circular disc of cardboard as shown in Figure 78. Paint one half of the disc black and the other half white. Mount a small red electric lamp behind the disc opposite the hole and rotate the disc. It is a good idea to cover the lamp with tracing paper if it is too bright or if the filament can be seen easily. Illuminate the front surface of the disc by a

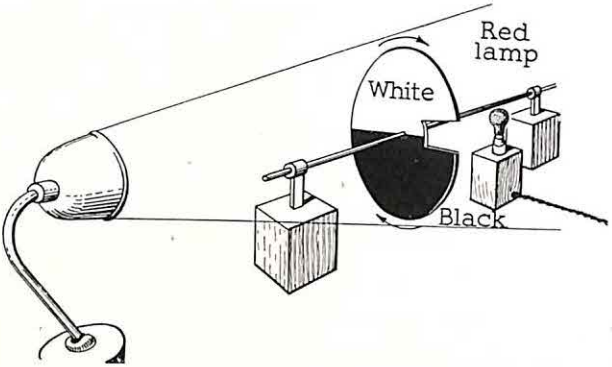


FIGURE 78.

strong white light. If the disc is rotated in the direction shown, the lamp will appear to change into its complementary colour. *What happens if the disc is rotated in the opposite direction? What will happen with other well-lit coloured objects in place of the red lamp? Why does this change occur?*

Paints. We have been considering coloured rays of light and using them to produce various colours on screens and other bodies. An artist does not use rays of light; he uses paints and obtains his effects by mixing various paints together.

What does a paint do to the white light which falls upon it? A paint absorbs some of the colours of white light and scatters others. It is difficult to obtain paints which scatter precisely one colour, most of them scatter a lot of one colour and a little of others. For instance, a yellow paint scatters a lot of yellow as well as a little red and a little green. Similarly a peacock blue paint which is a light blue paint scatters a lot of peacock blue, a little green and a little indigo. Thus if an artist mixes yellow and peacock blue paints he will obtain the only colour which both will scatter and that is green, all the other colours being absorbed by one or the other paints. He will get the same result too if he paints his white paper with yellow paint and then later paints over the yellow with some peacock blue paint. It will not be a bright green colour which results from this mixing because only a little green is scattered by both of the original paints.

An artist can prepare the various colour paints he requires by using three basic colour paints which he calls his primaries. If these paints have the same colour as the secondary light colours, and if he uses them on white paper, he can obtain by mixing them suitably, red, green and blue. In fact an artist does not call his primary paints magenta, yellow and peacock blue. He uses the simple words red, yellow and blue.

There are so many shades of all these colours that it is confusing to try to name them. Various colour codes are now in use in commerce for defining colours in terms of numbers. One such code has over 18,000 colours and is used by the textile and dyeing trades for matching colours of materials all over the world.

Colour printing in books and magazines is done by a process in which pictures in yellow, magenta and peacock blue are superimposed one on top of the other. In some methods the coloured areas are continuous whereas in others they are broken up into minute dots. When the picture is printed by the second method the eye sees all the dots from a distance and mixes the colours together. In both processes grey is used as well to obtain clear definition in the pictures and different depths of shade. Examine a number of good coloured illustrations with a magnifying glass to see which process has been used.

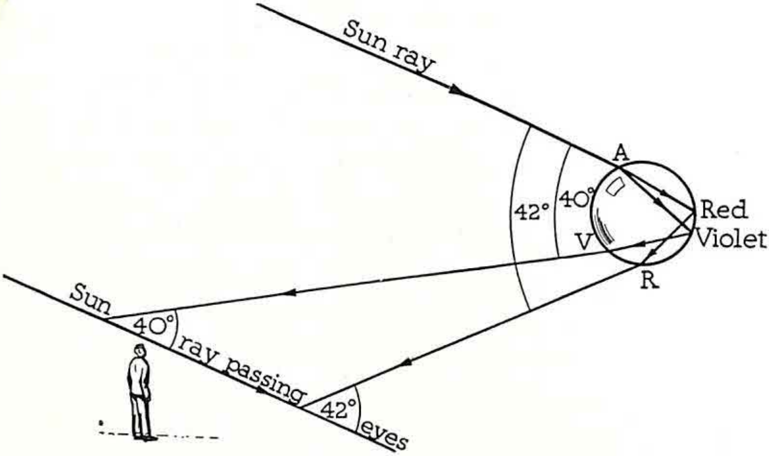


FIGURE 79. Single raindrop (greatly enlarged) reflecting coloured rays.

Problem C: What part does Colour play in Communication?

Question 3. **Why are there Colours in the Sky?**

Rainbows. We have all noticed the beautiful colours in the rainbow. They are the same colours and appear in the same order as in the spectrum. How does this come about? If during a rainstorm strong sunlight from behind our heads shines upon falling drops of rain in front of us, then a rainbow may be seen. Figure 79 shows how light from the sun is split up into its various colours on entering the water of the raindrop at A. These coloured rays are then reflected from the back of the raindrop and after bending once more as they leave at R and V come down to our eyes. But you remember in the experiment with the prism that the red ray was not bent so much as the violet ray. The same thing happens in the water, so that from one raindrop we are able to see only, let us say, a red ray and from another raindrop a little lower a violet ray. But all the reds will be at the same angle of 42 degrees

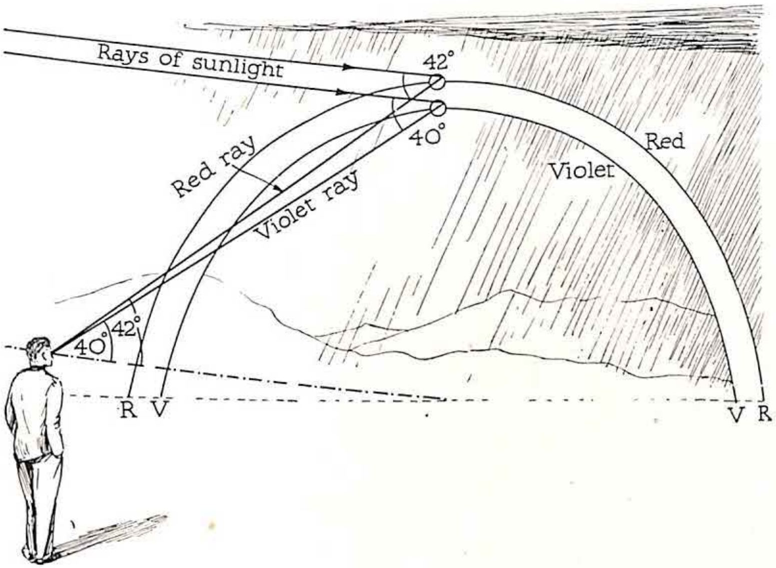


FIGURE 80. Two of countless raindrops in the form of a semi-circle reflecting coloured rays.

and all the violets at an angle of 40 degrees from the line formed by the shadow of your head as in Figure 80.

Do we all see the same rainbow? Do we see the rainbow in the same position as that seen by another person a few yards away? When next you see a rainbow examine its position from two places. *Which colour is on the outside of the bow?* Draw in your note-books two raindrops to show this. The drops producing the rainbow may not be more than a few yards away from you. We often think that these raindrops are a long way off. You can make your own rainbow when the sun shines strongly by using a fine spray of water from a garden hose-pipe. Observe your home-made rainbow from a height, climb up some steps and you may be able to see almost a complete circle. Ask a pilot if he has seen a complete rainbow below him when he has been flying high.

SOMETHING YOU MAY CARE TO DO

Make your own rainbow indoors. Fill a round-bottomed glass flask of diameter five or six inches with water and suspend it by its neck so that it does not swing about. Shine a strong parallel beam of light from a projector through a hole of about four inches in diameter in a white screen on to the flask. The light beam is then bent and reflected as in the raindrop so that a circular spectrum is clearly seen on the screen. It will be easier to see this spectrum if all the unwanted rays of light passing around and through the " raindrop " are caught on a dull black screen so that they do not dazzle your eyes.

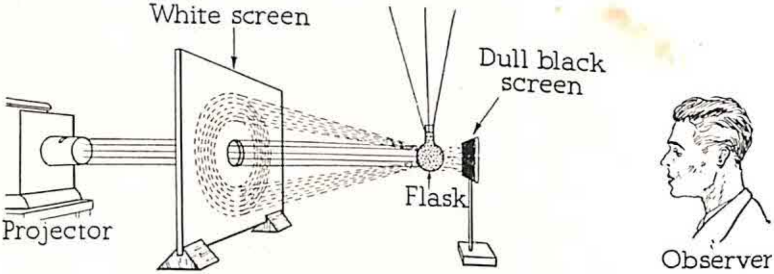


FIGURE 81. How to produce a circular rainbow.

Why is the sky blue and why does the sun set red? The air surrounding the earth has many particles floating about in it. The rays from the sun enter this air and some of the rays from the blue end of the spectrum are stopped and scattered to the side. The rays which remain, from the red end of the spectrum, travel on. A person looking up at the sky will thus see some of these scattered blue rays at the same time as someone else further away from the sun will see red rays on looking at the sun. This second person on watching the sun set will see rays which have passed

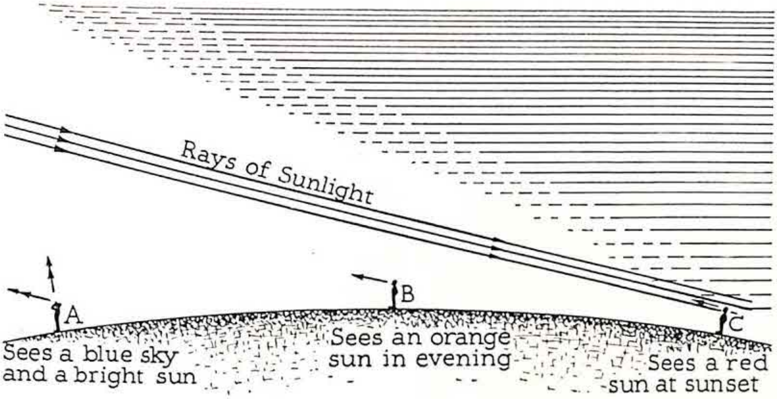

Rays of Sunlight
A
B
C
Sees a blue sky and a bright sun
Sees an orange sun in evening
Sees a red sun at sunset

FIGURE 82.

through more and more of the earth's atmosphere so that the only rays he will see will be those closer and closer to the red end of the spectrum. Have you noticed how the sun gets redder as it sets? Why are sunsets to the east of smoky industrial areas very beautiful?

There is so little air left ten miles up in the stratosphere that practically no light is scattered downwards: space-travellers would look out into an empty black space.

SOMETHING YOU MAY CARE TO DO

It is possible to show this effect of the scattering of the blue rays quite clearly with a simple piece of apparatus. Shine an intense beam of light from a projector through one end of a long glass tank so that the rays come out at the other end. A long aquarium is suitable. Nearly fill the tank with a weak solution of photographer's hypo (about a teaspoonful to a quart of water). Slowly add dilute hydrochloric acid and

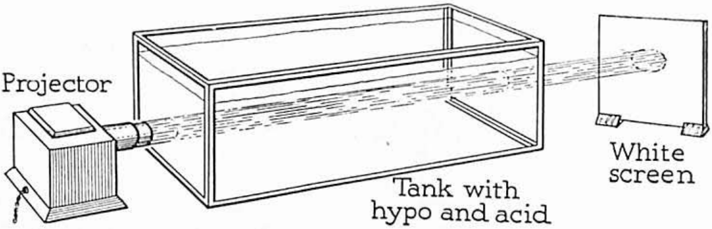


FIGURE 83. How to produce blue sky and a sunset.

keep stirring thoroughly with a stick. A faint cloudiness of fine grains of sulphur will soon appear in the tank. This cloudiness will steadily become more noticeable. Either look through the end of the tank or allow the light to fall upon a white card placed there to receive it. *What do you notice happening to the rays in the tank? Would you agree that the circle of light on the card resembles the setting of the sun? Would you say, as a result of this experiment, that small particles in the medium through which light passes scatter some of the light so that only a part of the light can penetrate? Which colour of white light is best for penetrating a mist or fog?* Why does the removal of the blue end of spectrum by a motorist's fog lamp assist him?

Problem C: What part does Colour play in Communication?

Question 4. **Are there Rays which we cannot See?**

Infra-red rays are given out from an electric fire bar just before it begins to glow red giving out red light rays. These rays are even better than the red light rays for penetrating through haze and mist. The human eye cannot see these infra-red rays but some photographic films are sensitive to them. These infra-red photographs are especially useful when mapping distant country and mountain ranges.

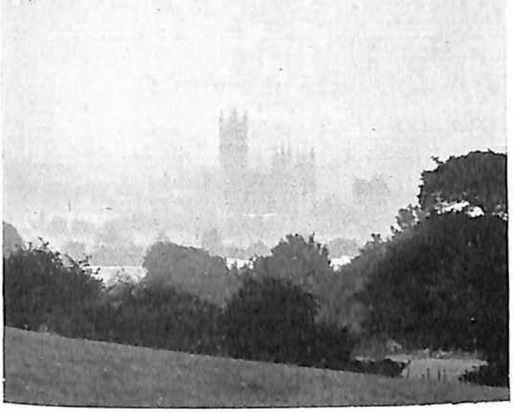
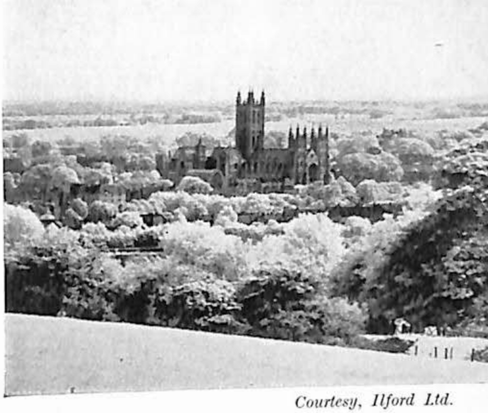


FIGURE 84. View taken with visible light.



Courtesy, Ilford Ltd.

FIGURE 85. Same view taken with infra-red rays.

A box giving out infra-red rays is sometimes concealed at one side of a doorway. At the other side a sensitive receiver is installed. This switches on an electric current to open the door if a person passes through the ray in order to enter. Can you think how such a system can be used as a burglar alarm ?

Smoke screens and vapour trails in the sky are both due to the scattering of light by small particles. The smaller the particles the better is the screen produced.

Ultra-violet rays are at one end of the spectrum and infra-red rays at the other, as you see in Figure 86.

The ultra-violet rays, like the infra-red rays, cannot be seen with our eyes. These rays are stopped and scattered in the air more easily than the violet and blue rays. However, some of the ultra-violet rays from the sun do get to us near sea level to enable us to produce through our skins vitamin D so essential for the prevention of such diseases as rickets (see Unit 4 page 60). Unless our bodies have been gradually accustomed

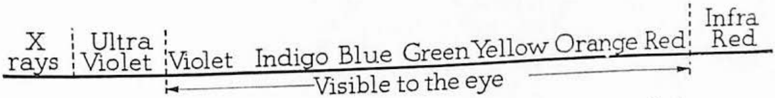


FIGURE 86. The Spectrum. (Not drawn to scale.)

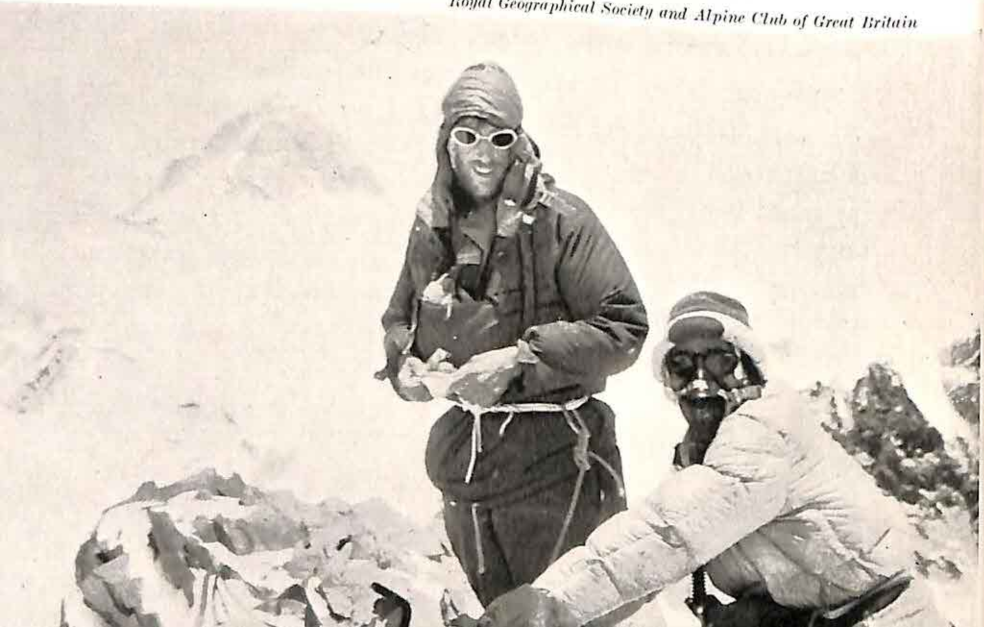
to the ultra-violet rays, then a sudden exposure to strong sunlight for any length of time, as in sunbathing, will produce sunburn and sore blisters which will let in all kinds of stray infection. Gradual exposure will allow the body to develop slowly a tan which acts as a protection for the skin.

"Snow blindness" is caused by the reflection of ultra-violet light from mountain snowfields. At high altitudes the rays from the sun have less air to penetrate and thus mountaineers must cover their skins with a protective cream if they wish to prevent severe sunburns.

We have learnt that, in the presence of chlorophyll, sunlight changes water and carbon dioxide into sugar and oxygen (see Unit 4 page 46). It is the ultra-violet part of sunlight which is mainly responsible for this. Ultra-violet light is only present in large quantities during the middle hours of the day in the summer. This is therefore the period of rapid growth.

FIGURE 87. Everest, 1953—Hillary and Tensing. Why do they protect their eyes with yellow glass in their goggles?

Royal Geographical Society and Alpine Club of Great Britain



Most cold bodies can only be seen because of the light which is reflected from their surfaces. They are invisible in the dark and can at best only reflect the colours in the light which falls on them. The moon and the planets only appear bright because the rays of light from the sun strike them. In some positions sunlight does not strike all the face of the moon which is turned towards us and thus less light reaches us from the moon at night when it is in its first quarter than at full moon. Mars is red because its surface is made of a material which reflects red light and absorbs all the other colours.

Stars, meteors and comets emit their own light because they have a high temperature like the sun or a fire. We wonder now if it is the smashing of the atoms in the stars which liberates energy to keep the stars hot so that they continue to give off light and heat.

As the temperature of bodies rise, so the main "colour" of the light given out changes from infra-red to ultra-violet. At the same time a continuous range of "colours" is always emitted. A carbon arc light is nearly as hot as the outer surface of the sun and gives nearly the same spectrum. An oil lamp or a candle is much lower in temperature and gives a yellow light.

Why is the modern coiled coil filament such an improvement over the old straight filament type of lamp?

Some substances, like the expensive radium for instance, give off light and remain cold. Other substances absorb light during the day and give off light of a slightly different colour at night.

Butterflies and glow-worms which are not hot bodies give off light as they use up some of their energy. A vast number of other living organisms from bacteria to some kinds of shrimps, spiders and fishes can give out lights. Some centipedes which give out light can be found in England and Europe. It is reported that when English soldiers marched over damp meadows to the trenches in northern France in 1916 the centipedes were so numerous and so bright that officers thought the men were disobeying the order not to smoke.

SOME THINGS TO THINK ABOUT

1. Why do some coloured substances like coloured glass or copper sulphate crystals appear white after they have been crushed to a very fine powder ?

2. Why do things appear of different colour when viewed by artificial lights than when viewed by sunlight ?

3. Why are red neon lights very effective as aeroplane beacons in all weathers ?

4. In what direction is a rainbow seen in the afternoon ? In the morning ?

REVIEW QUESTIONS

1. Give two reasons why there is so little sound in the stratosphere (ten miles above the earth).

2. It is the energy of the sound waves that makes a sound record for a gramophone. (*a*) What is the source of the energy that produces the sound when the gramophone record is played ? (*b*) Why is the reproduced sound often louder than the one recorded ? (*c*) Why is it often of a different pitch ? (*d*) Why is it often of a different quality ?

3. What causes the sound of the human voice ?

4. Which (usually) produces the more sound waves per second : a soprano or a bass singer ?

5. Why does pinching the nose while speaking or singing change the quality of the voice ?

6. Why does an empty room sound " hollow " ?

7. Why does a band sound louder to people close to it than to those at a distance ?

8. How does light travel ?

9. Why are shadows often harmful on farms ? How may farmers usually avoid having undesirable shadows ? Of what value are shadows ?

10. For what purposes are mirrors used in shops ?

11. What kind of mirror might be used to start a fire ? How should it be used ?

12. Account for the fact that during a partial eclipse of the sun in summer the ground under the trees is likely to be covered with crescent-shaped spots of light.

13. Can you think of some ways in which a human eye is unlike a camera ?

14. What are the useful things to do for the proper care of the eyes ?

15. What will be the colours of the Union Jack seen through (*a*) a red glass, (*b*) a blue glass ?

APPLYING WHAT YOU HAVE LEARNED TO EVERYDAY LIFE

1. Why does a deaf person sometimes hear better if he cups his ear with the hand or uses an ear trumpet ?

2. Why do sailors on battleships hold their mouths wide open when a big gun is fired ? What help does this give ?

3. A boy in a school orchestra said, " I enjoy it, but it is hard work." What work, if any, is done by a boy who plays a horn ?

4. The bullet from a revolver travels about 500 feet a second. If such a bullet passed close to the ear of a distant animal, would it hear the whiz of the bullet before or after it heard the report of the revolver ? Answer the same question for a rifle bullet having a speed of 2000 feet a second.

5. Why is there less sound in a telephone booth if it has a double window in place of a single one ?

6. Why do the eyes tire more when doing " close work " than when viewing distant objects ?

7. What is meant by "focusing a camera"?

8. Why are lantern slides placed upside down in a projector?

9. Why should the source of light be above and behind you when you are reading at night?

MORE FOR THE SCIENCE CLUB TO DO

Make a lens and take a picture, using watch glasses. Two ordinary watch glasses will do, but the larger kinds used in chemistry are more desirable.

Arrange the glasses as shown in Figure 88 (*a*). "Bostick" cement is desirable, but rubber solution is satisfactory.

In order that water may be placed in the space between the glasses, a small notch should be filed in the edge of each of them. If the notches are placed next to each other, a suitable opening will be formed. After the lens is filled with water, this opening may be closed with a bit of wax.

The apparatus needed for using the lens is shown in Figure 88 (*b*). It is desirable to blacken the end of the box to which the letter M is fastened, or it may be covered with some dull material that does not reflect light. Do not use black enamel, because it reflects too much light. After the lens has been fastened over the hole in the cardboard, adjust the positions of the lens and the screen so that a clear image of the letter M can be seen upon the screen. Then turn off the light and pin a piece of blue-print paper to the screen with drawing pins so that the image of the letter will fall upon it.

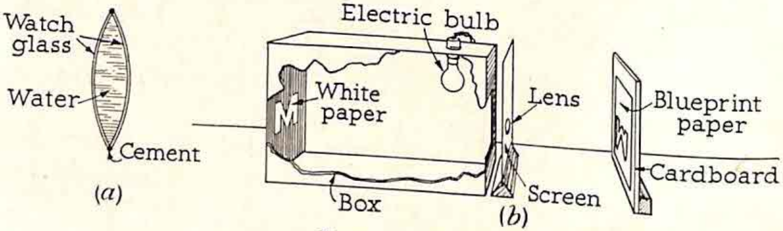


FIGURE 88.

SCIENCE ON THE MARCH

THE FIRST NINE UNITS

The Air and You
Water and Life
The Weather and the Earth
Life and Food
Health
Energy and Engines
Hearing and Seeing
Electric Currents
Magnets and Motors

LONGMANS